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FPL 1962

Annual Report of the Forest Products Laboratory

Forest Service, U. S. Department of Agriculture

FPL 1962: Annual Report of the Forest Products Laboratory

FOREWORD

The first duty of a research laboratory is to do research. But the doing is only a part of the whole job. As scientists long ago learned, the findings of research must be reported, the new knowledge shared. In an earlier time, the goal of publication was simply to let one's colleagues know, so as to avoid endless and profitless duplication and provide a foundation for further research. That limited goal has undergone extensive broadening until today it includes all major media of communication, because scientific knowledge and the technologies it has spawned pervade virtually every walk of life. In no major area of research is this more evident than in forest products.

In this annual report, the Forest Products Laboratory presents a summary of its work for the year 1962. Some highlights are:

- Announcement of research findings that constitute the technological basis for a southern pine plywood industry.
- Development of a variety of structural building components from low-quality ponderosa pine grown in Arizona and New Mexico.
- Investigations of the potential of water jets and lasers for wood cutting.
- Development of a highly satisfactory materials handling pallet of aspen—an improved use for this plentiful wood.
- New knowledge of lignin's molecular structure.
- New applications of PEG (polyethylene glycol) for stabilizing wood products dimensionally.
- A method of prestressing glued laminated beams to improve load capacity.
- New engineering designs for fire lookout towers.
- New knowledge of effects of pulping processes through microscopic study of pulp fibers.
- Evidence of bacterial degradation of wood—a basis for modification of preservative treatments.

The variety of scientific and engineering disciplines necessary to produce such tangible results is readily apparent. Yet they represent by no means all of the resources of science and technology regularly employed at the Forest Products Laboratory in the carrying out of its program of research. In no one year, of course, can every project, every study under way be expected to contribute such major findings and accomplishments. Every experiment carries within it the seeds of failure as well as of success—one cannot predict how it will flower.

Yet the ten highlights listed above collectively comprise substantial gains along a wide front. Fundamental research and functional applications are alike represented, and properly so. In any comprehensive program, each type can be expected to advance the other.

The research reported herein is necessarily limited and selective. A list of 1962 publications giving more detail is appended.

Edward G. Locke

EDWARD G. LOCKE
Director

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Windows of the Forest Products Laboratory glow brightly as daylight fades into an early winter evening.

INTRODUCTION

The work of the Forest Products Laboratory continued during 1962 to be directed toward fulfillment of its threefold national responsibility: (1) to increase the serviceability of wood products in whatever form; (2) to develop new uses for wood and improve existing ones; and (3) to augment the usefulness and quality of all wood species.

Organizationally, FPL functions in five broad fields of research, which collectively span the full spectrum of forest products utilization. They are Wood Quality, Wood Engineering, Solid Wood Products, Wood Fiber Products, and Wood Chemistry. This report summarizes major research developments of 1962 under the same headings.

From an organizational standpoint, 1962 was a year of preparation as well as of fulfillment. The appropriation by the Congress of $200,000 with which to finance planning of the first major addition in 30 years to its physical plant made possible a start on specific preparations for future growth and, in particular, expansion of its work in pulp and paper and other fiber and chemical products. The year was also marked by acquisition from the University of Wisconsin of a 12-acre tract adjoining the present Laboratory grounds. It is planned to erect a $4,000,000 building on this tract to house the expanded fiber and chemical products research when funds become available. The land acquisition constituted one more concrete demonstration of the long and mutually beneficial cooperation between the Laboratory and the University.

The assignments of the Laboratory, during 1962 as in other years, were conducted on a truly nationwide basis; forest products research by its very nature entails much work in forest, mill, and factory as well as in the laboratory. Staff members continued to work on a wide variety of technical problems in every part of the United States, applying their technical and scientific knowledge and skills on behalf of producers and consumers of forest products. Typical of this work were the collecting of wood samples for quality evaluation of the forests of the West and South, the development of technology for a southern pine plywood industry, laboratory assessment of the properties of Hawaiian hardwoods, compilation of existing knowledge of Alaska woods, and analysis of utilization possibilities for low-quality white pine in New England.

This nationwide activity has been greatly facili-

tated by the ten Forest Service Experiment Stations strategically located throughout the country. Their Divisions of Forest Products Utilization Research function effectively as regional representatives of the Laboratory and perform many liaison services. During 1962, Station personnel carried out regional problem analyses as guides to FPL program planning, made cooperative arrangements with regional and State agencies, and consulted with regional industries on the application of Laboratory research results. Station scientists conducted applied research aimed at solving regional utilization problems.

Wood producers, processors, and consumers also made full use of FPL facilities and staff. Some represented national organizations; others came or wrote or called as individuals. Technical conferences were conducted in such fields as structural engineering, packaging, pulp and paper, wood preservation, and adhesives. Cooperative research with private industry involved 125 separate studies in Fiscal Year 1962, ending June 30, 1962. Laboratory personnel participated in national meetings of such scientific and technical organizations as the American Chemical Society, the Forest Products Research Society, the Technical Association of the Pulp and Paper Industry, and the American Society of Agricultural Engineers.

Cooperation with other Federal government agencies included the Federal Housing Administration, the Department of Defense, the State Department, the Building Research Institute, the U. S. Department of Commerce, the Agency for International Development, and, of course, other branches of the U. S. Department of Agriculture. Cooperation with State governmental units was extensive, especially in areas throughout the West, South, and Northeast where timber quality surveys were in progress. A number of colleges and universities with appropriate facilities were conducting research under grants of funds or cooperating in other ways with FPL.

In sum, this cooperative work with private industry and various public and educational agencies provides a wealth of opportunity to put results of research into use or to develop fresh information. Whether FPL publications, for example, go to a sawmill operator, a manufacturer of furniture or paper, a government official charged with structural inspection and public safety, a homeowner, or a student preparing himself for future work in forest products, the ultimate result is more efficient use of wood. Much the same is true of participation in and sponsorship of technical meetings, consultation with visitors, field trips to study industry conditions, and the voluminous correspondence with wood processors and users throughout the Nation and the world.

And the benefits are mutual. From all these multitudinous contacts, FPL scientists gain invaluable insight into the needs and problems of a Nation for research on wood.

In the following pages is presented a digest of FPL work in the laboratory, in the forests and mills and factories, and in classrooms and meeting halls during 1962.

WOOD QUALITY RESEARCH

The criteria of wood quality differ markedly, depending on the product made. The broad range of uses to which wood is put is chiefly accountable for these differences. For example, the machining and finishing properties that so largely determine quality of wood for fine furniture are obviously in marked contrast to the premium usually put on strength coupled with ease of nailing and cutting when selecting wood for structural framing.

These general quality considerations are applicable when choosing woods for a given purpose. Within each species, however, quality variations may have even greater significance. The strongest pieces cut from a log are generally those with the straightest grain and the fewest blemishes, such as knots and decay. Grading rules, usually tailored to a species and its various use categories, are applied to segregate material of various qualities and values.

From the research standpoint, quality considerations are even broader. Involved are such factors as determining how quality is related to wood structure and how structure is in turn affected by growth conditions such as soil, rainfall, sunlight, elevation, and stand density, and such management practices as pruning, thinning, and the like. The scope of wood quality research at FPL encompasses all such considerations.

Effects of Soil Fertility

During 1962 a unique investigation was begun into the effects of soil fertilization upon wood quality over a period of almost 30 years. The opportunity to make this assessment arose under unusual circumstances.

In the early 1930's, elaborate and comprehensive soil fertilizer studies were begun in second-growth hardwood stands of the privately owned Black Rock Forest near Cornwall-on-Hudson, N. Y. Initial results were published in a series of bulletins and papers during the next few years. The forest was subsequently acquired by Harvard University and maintained in largely undisturbed condition. It thus became possible last year for FPL and the Central States Station to enter into a cooperative agreement with Harvard to obtain logs of red oak, green ash, and yellow-poplar from the original quarter-acre plots, which had been fertilized with different amounts of nitrogen and phosphorus. Also, tree leaf samples were collected from the variously treated plots at different periods following fertilization.

At FPL, an intensive study was begun during late 1962 of the specific gravity, structural and anatomical features, and machining characteristics of specimens taken from the logs. Rate-of-growth studies showed that maximum growth response to fertilization—as much as 400 percent—occurred within 3 years after the original fertilizer treatment. Effects of fertilization, especially with nitrogen, have been found to continue much longer than expected on the basis of the original studies a quarter century ago. The investigation is continuing.

In companion studies, scientists at the Ames Research Center of the Central States Station are investigating long-term physiological effects and trends, such as nutrient levels in the leaves as well as in the soil, at various periods following fertilizer applications.

Marking green ash log, for guidance of sawyer, along annual ring where accelerated growth began after fertilization of soil in Black Rock Forest during early 1930's.

M 121 861

Environmental Effects on Growth

A tree trunk can be graphically represented by a series of cones nested one in another, each representing a layer of annual growth. Studied thus, actual trees have yielded important information on how they grow with respect to soil moisture and other environmental factors. The latest series of such studies at FPL, now under way, involves loblolly pine, one of the southern pines. The method affords a realistic picture of overall stem growth, indicating for each cone, or increment sheath, the areas along the length of the stem where annual accretion of summerwood and springwood is greatest or least. This is in turn related to weather records, growth site quality, and the like.

Two groups of 17-year-old loblolly pine trees are being studied in this way by dissecting them anatomically at various points along the stems and analyzing the results by statistical methods. One group was cut from a higher-quality growth site than the other. For comparative purposes, several 34-year-old trees were also cut from the better quality site.

Data from the younger trees show definite growth patterns that are markedly affected by seasonal differences in soil moisture. During years of relatively abundant rainfall, springwood and summerwood growth patterns are accentuated, while in comparatively dry growing seasons growth is much more uniform in the increment sheath being produced that year. Effects of site quality are similarly apparent; summerwood is less affected than springwood on the poorer sites, hence wood is somewhat more dense (about 6 percent) because summerwood is denser than springwood. On the other hand, overall volume of wood produced on the poorer sites is very much smaller (about 60 percent), more than offsetting the density gain.

The older trees were found to be much less responsive to these environmental differences, and wood structure and properties were much more uniform throughout the length of the increment sheaths.

This study is expected to demonstrate, when complete, certain limitations within which timber management practices can be applied to loblolly pine to attain better and more uniform tree growth, hence higher quality wood, as by increasing rotation age and encouraging initial rapid height growth of trees to obtain higher percentages of high-density wood. Similar research on other species could be expected to yield comparable guides to timber management.

Quality of Standing Timber

In the 1961 annual report, the background and objects of softwood timber quality surveys in 11 Western States, most of the South, and Maine were set forth in detail. During 1962, substantial progress was made in all four phases of this virtually nationwide tree quality census, which is unique in the history of forestry.

The four phases of this research undertaking are (1) collection of increment cores from trees in statistically selected sample plots; (2) laboratory determinations of specific gravity, age, growth rate, sapwood thickness, and the like; (3) relationship of the specific gravity of increment cores taken at breast height to that of wood elsewhere in the usable length of the stem; and (4) basic strength tests, as necessary, of clear wood and plywood from all major species, covering the range of specific gravities found in phases 1, 2, and 3. (Progress in Phase 4 studies is reported under Wood Engineering Research.)

With the exception of three western hardwoods, black cottonwood, red alder, and bigleaf maple, all sampling has been limited to softwoods. In the South this has involved the principal species of southern pine; in Maine the spruces, firs, eastern larch, eastern hemlock, and the pines; and in the West some 30 species including Douglas-fir, redwood, western hemlock, western larch, Sitka spruce, Engelmann spruce, western redcedar, ponderosa pine, sugar pine, western white pine, noble fir, and white fir.

Increment core sampling of the western species was completed during 1962. In all, nearly 30,000 cores were collected by crews of the Pacific Northwest, Pacific Southwest, Intermountain, and Rocky Mountain Forest and Range Experiment Stations from 4,067 sample plots in 11 States. By the end of 1962 most of these cores had been processed at FPL for specific gravity, which is a reliable index of strength properties and pulp fiber content. The information, when processed and analyzed, is expected to shed much light on the range of properties for the various species being surveyed. Heretofore, such information about these species has been quite limited because relatively few trees had been sampled in widely scattered areas.

Analysis of the laboratory data is expected to be completed with aid of high-speed computers during 1963, and a final report on the findings of the western survey is planned by mid-1964.

Three major western industry groups, the Douglas Fir Plywood Association, West Coast Lumbermen's Association, and the Western Pine Association, are contributing $300,000 to the survey under a cooperative agreement with the Forest Service. Findings are expected to be of great value in the management and harvesting of forests, the manufacture and marketing of lumber, plywood, and other products, and more efficient utilization of lumber and plywood in construction.

M 121 456

Many thousands of increment cores from living trees, such as this one being weighed, are yielding comprehensive data on wood quality of standing timber throughout the West, South, and part of New England.

Meanwhile, Phase 3 work involving the collection of disks from various heights in trees and comparison of wood thus obtained with that in breast-high increment cores was brought substantially to completion for the major western species. As a result, necessary correlations have been worked out for interpretation of increment core data obtained under Phases 1 and 2. This work has involved felling and sampling of 1,423 trees at 47 locations in 8 States. About 8,000 disks thus obtained have been processed, and preliminary statistical analysis of specific gravity data was completed.

More refined statistical analyses are being continued with the aid of an electronic computer to evaluate more closely the effects of stem diameter, age, volume, and other tree characteristics on specific gravity. The 10-inch-long increment cores obtained from the western species, in large trees representing only a partial radius, show closer correlations with whole-tree gravity obtained from disks than was the case with full-radius cores taken from the southern pines. This is due mainly, of course, to the fact that wood near the pith of trees varies considerably in density from that grown later in the tree's life. The later wood constitutes the bulk of the tree trunk; a full-radius increment core, therefore, gives disproportionate importance to the comparatively small amount of juvenile wood.

Several additional western species may be sampled for tree-length specific gravity variations under Phase 3 of the program during 1963.

In the South, where the increment core survey program got its start several years ago as part of the Forest Survey of Mississippi's southern pine stands, work has meanwhile continued throughout the southern pine belt.

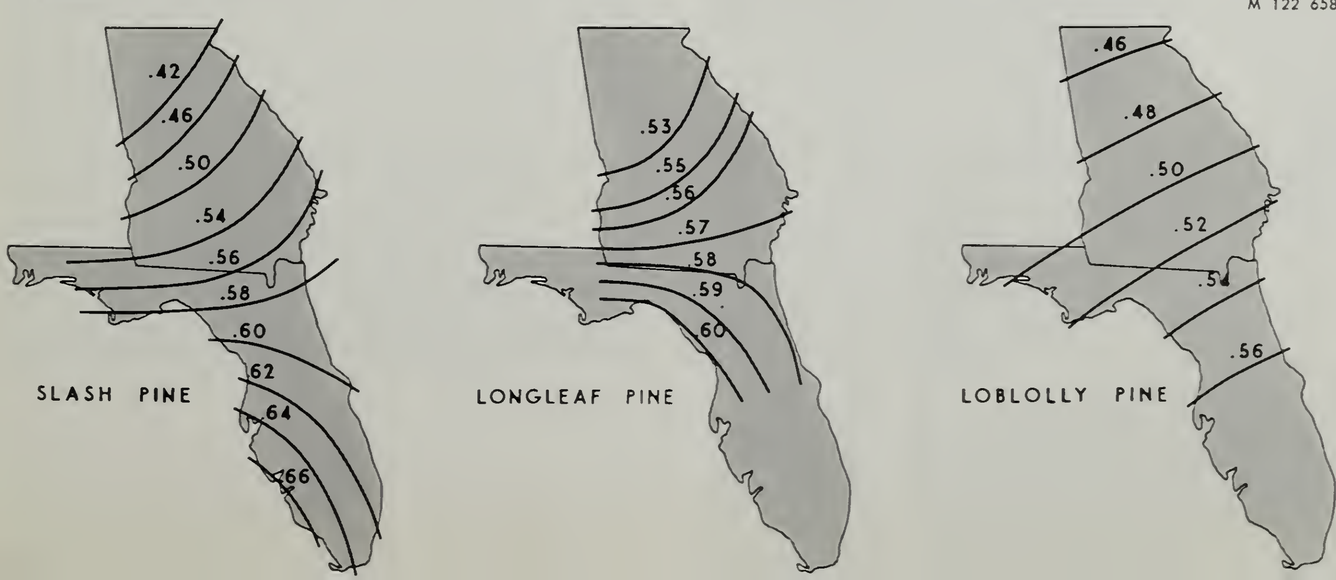
Field collection and laboratory analysis of increment cores were completed in Arkansas, Georgia, and Florida, and are expected to be completed in Alabama and North Carolina by mid-1963. Field work was scheduled to begin in Louisiana in early 1963. Reports covering major findings of the statistical analysis of cores collected in Arkansas, Georgia, and Florida were in preparation at year's end.

Among significant findings of the surveys in Georgia and Florida was the trend toward increasing specific gravity of wood continuously from northwest to southeast through both States. The pattern of variation is quite similar to that originally found in Mississippi, except that latitude appears to have a greater effect on slash and longleaf pine. This appears to be especially true for Florida, and is thought to be due to local climate and soil conditions.

Slash pine, the most widely distributed species in Georgia and Florida, ranged in average specific gravity from 0.42 in central Georgia to 0.66 in southern Florida. Loblolly pine's variation was not so great, from 0.46 in the north to 0.56 in the south of this range, and longleaf pine varied least, from 0.52 to 0.60.

Patterns of variation in specific gravity, as shown by wood density surveys, for three southern pine species in Georgia and Florida.

M 122 658



One of the major markets for southern pine in this area is for pulpwood, and specific gravity has this practical significance for pulp mill operators: An increase or decrease of only 0.02 in specific gravity means an increase or decrease of 100 pounds in the weight of a cord of dry southern pine pulpwood, or 50 pounds of dry pulp obtainable from a cord. These values indicate why the trend is strongly toward marketing pulpwood by weight instead of volume.

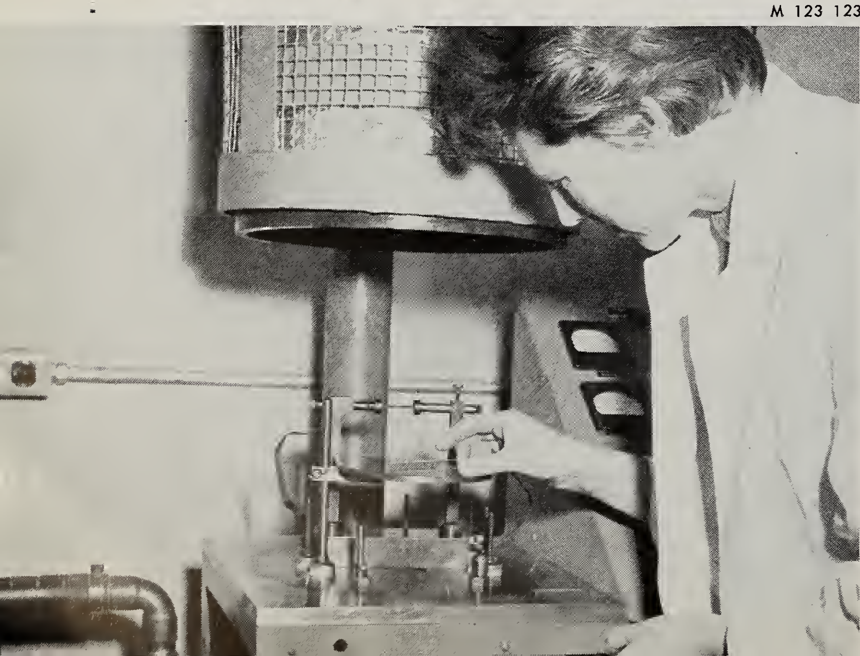
Published relationships between specific gravity values obtained from increment cores taken at breast height and those obtained from disks taken at various heights in trees are being refined with data obtained from Arkansas and the Georgia–Florida area. The refined relationships will apply to trees of a greater range of diameters than data presently available.

Substantial assistance in manpower and other aids has been received in the southern States from industry and State foresters by the Southern and Southeastern Forest Experiment Stations, which have conducted the increment core collection work and cooperated with FPL staff members in whole-tree sampling for overall tree density data.

In Maine, industry is doing all the field work of collecting increment cores from softwood species, and core processing is being done by the University of Maine with industry financing. This work was about 65 percent complete at the end of 1962 and is scheduled for completion in 1964. Overall tree density sampling in Maine, being done jointly by the Bangor Research Center of the Northeastern Forest Experiment Station and FPL, was about 90 percent complete.

Electron microscopist Lidija Murmanis inserts glass slide containing plastic imprints of wood specimens in device for coating them with carbon. When hood is lowered, air is withdrawn and electric current vaporizes carbon. Technique is used because wood may be damaged by electrons at high magnifications.

M 123 123



Structure and Quality

The basic importance of wood structure to its use and service life becomes more clearly revealed as more is learned about it with the aid of refined instruments and techniques. As reported last year, the electron microscope has greatly enlarged this field of investigation and multiplied the possibilities of improving utilization through basic structural research.

A major line of study on which solid progress was made was the investigation of lignin distribution in the cell walls of white spruce, loblolly pine, and sugar maple. Results reported last year were amplified and confirmed by additional studies that showed the greatest density of lignin to be in the middle lamella, the primary wall, and the S_3 layer. In the secondary wall it exists as a branched three-dimensional network interspersed around the crystalline cell-wall structure. Greatly facilitating these studies was a chemical method of slide preparation based on the use of hydrofluoric acid to remove the carbohydrates, leaving only lignin. Heretofore the S_3 layer of the cell wall had been believed to be relatively free of lignin, and the findings have a strong bearing on chemical pulping research to obtain greater yields and better fiber bonds in paper sheets.

The value of the electron microscope in forest products research was demonstrated also in connection with new studies of bacteria that are found in wood. A metal shadow-casting technique which consists essentially of laying a thin cover of vaporized metal on a specimen was used to establish the existence of flagella on bacteria taken from wood. These long, thread-like projections enable bacteria to move in various media. Work under way is reported under "Solid Wood Products Research."

The Laboratory's senior electron microscopist was granted a year's study, under Public Law 85–807, of electron microscope techniques used in Germany, the first Forest Service employee to receive such training abroad.

Electron microscope studies also demonstrated that the bordered pits in the cell walls of Coast and Inland Douglas-fir are quite similar—a fact of significance in the preservative treatment of these two varieties, since liquid preservatives penetrate the wood largely through these cell-wall openings.

Lumber Quality-Yield Studies

A field investigation of the clear-wood yield potentials of Standard grade (No. 4 Common) eastern white pine 1-inch boards demonstrated that application of cutting techniques commonly used with hardwoods to obtain clear pieces that could be rejoined with glue to make large clear panels

might be economically feasible. Boards of this quality, which contain knots, decay, splits, wane, and other imperfections, comprise about 50 percent of production in New England mills.

The FPL study was conducted in cooperation with the Northeastern Forest Experiment Station at the request of the Department of Commerce with the cooperation of ten New England sawmill operators. Some 5,000 boards were examined for potential yield of clear cuttings at 10 sawmills, careful measurements being made on 1 of each 10. Potential yield could be fairly accurately estimated by inspection, it was found. Boards of the grade would yield a little better than half their volume in clear cuttings. This was considered an adequate yield to promise commercial success because the value of the glued-up large clear panels would more than offset the cost of the Standard-grade lumber and cutting and gluing costs.

As a result of this investigation, the Department of Commerce loaned a businessman funds for establishing a mill to produce clear material from this grade of white pine.

A somewhat comparable but more extensive investigation is under way on the yield potential of various factory grades of 1-inch hard maple lumber. Field work is being done at the Carbondale, Ill., Wood Products Pilot Plant of the Central States Forest Experiment Station, under supervision of FPL. Some 10,000 board feet of lumber are being evaluated for yield of clear cuttings from various grades by recording defects according to position in the board. When these data have been fed into electronic computers, it is hoped that firm estimates can be made on the yield of high-quality cutting of various sizes from specific grades of hard maple. Such information would be of great value to furniture and other manufacturers in estimating their needs for various grades of this hardwood in terms of cutting sizes needed for specific parts. If the results confirm expectations, similar work may be done on other hardwood species.

Log and Tree Grading

During 1962 the Laboratory continued its cooperation with the Forest Service National Log Grade Committee in a technical advisory capacity, reviewing work plans and technical reports prepared by various Stations and consulting with project leaders from various parts of the country. Currently this technical backstopping covers five projects, northern softwoods, southern pine, hardwoods, ponderosa pine, and Douglas-fir.

FPL specialists also completed a "Guide for the Selection and Control of Study Sawmills" intended to insure that lumber grade recovery data collected from mills operating at a controlled level of efficiency will be comparable. Mill trials of the Guide will be made this year.

A set of hardwood veneer grades designed for use in developing log-grade specifications for hardwoods to be cut into veneer was tried out on sweetgum logs at a veneer mill in Georgia. The trial, most recent of several on different hardwood species, indicates that the grades are practical for use in veneer-log-grade specification studies.

FPL photographic specialists trained Forest Service field workers in camera techniques for use in mill studies of lumber yield from logs. This important phase of the log-grade project facilitates the taking of photographic records of log yields for analytical purposes.

FPL grading specialists also assisted in a training course in log and tree grading in Alaska.

Sawmill Improvement

Sawing round logs into square-edged lumber has been going on for centuries. Slabs, edgings, and sawdust are still ample evidence, however, that there remains much room for improvement in machinery and techniques. In this area, FPL sawmill specialists are pushing a series of promising investigations.

One of the keys to greater sawmill efficiency is the design of sawteeth used on circular saws. A critical point in tooth design is the so-called back-clearance angle of the sawtooth. A study in progress is designed to explore the effect of this angle on power consumption, feed rates, sawplate shoulder breakage, and certain other tooth design factors. A saw on which this tooth angle can be infinitely varied is being used in experiments to determine which angle is most efficient. From results, it is hoped to be able to prescribe more exact tooth angles—not only for back clearance but for hook and sharpness—in saw designs.

FPL's Duo-Kerf saw principle, which incorporates alternate chipper and planer teeth, has been successful in shop saws. It is now being restudied with a view toward making it more suitable for sawing logs. This arrangement of sawteeth produces a smoother cut than conventional teeth, for many purposes eliminating need for further surfacing. Changes in tooth geometry give promise of making the saw more efficient on logs. In addition, a new device for sharpening Duo-Kerf teeth with a radial arm grinder was devised that greatly simplifies saw maintenance. In trials under commercial operating conditions, the saw performed well on straight-grained logs. Further changes in tooth geometry are being worked on to adapt the saw better to the cutting of logs with so-called "wild" grain.

M 123 671

High-speed photography reveals cutting action of various types and designs of sawteeth used on circular saws.

A mathematical study of the relation of log diameter to saw kerf demonstrated that, for log diameters down to $5\frac{1}{2}$ inches, width of kerf has a significant effect on yield of dimension lumber. The average yield increase was slightly over 7 percent for sawing with a 9/32- rather than a 12/32-inch kerf. The study also showed that if logs are carefully segregated according to diameter into product groups, recovery gains of up to 15 percent can be realized regardless of kerf width used in sawing.

Dimensional Stabilization

The tendency of wood to swell and shrink with marked changes in atmospheric humidity creates problems when it is used for products where stability is essential. Among these are furniture, woodenware, statuary, gunstocks, and various types of novelties. Protracted or extreme changes in humidity can cause wood products to swell or shrink enough to loosen glued joints, open checks or cracks, change shape, and impair shooting accuracy.

During 1962, experiments were continued with polyethylene glycol (PEG) as a chemical stabilizing agent. The most notable successes were achieved in cooperation with the U. S. Marine Corps Rifle Marksmanship Team, which used a number of weapons equipped with PEG-stabilized gunstocks. Target rifles so equipped were credited by Marine shooters with providing a competitive edge that aided them materially in winning a number of important matches during the year. The season's competition was climaxed by the winning of the coveted Herrick Trophy by a Marine six-man team at the National Matches at Camp Perry, Ohio. The success of the Marines focused attention of competing organizations and individuals on stabilized gunstocks.

Wooden statuary and other carved pieces of art often purchased by American travelers abroad are frequently made of poorly seasoned wood, especially in tropical lands where high humidity makes it impossible to air season wood to the low moisture levels essential for use in the United States. As a result, when purchasers bring their mementos into winter-heated homes, shrinkage and warp frequently result in checking and splitting.

Treatment with PEG has been found effective in preventing such damage if done in time. The inadequately seasoned wood must be soaked in water for about 2 weeks to restore it to a condition approximating that of green wood. First, however, any varnish or other finish must be removed. The water-soaked object is then immersed in a PEG-water solution as is done in treating newly cut green wood. Well-treated specimens can be finished with polyurethane varnish, which has been found to adhere well to the treated wood when applied as directed in available FPL technical reports on the subject.

In response to inquiries about the applicability of PEG treatment to woodenware, some experimental runs demonstrated that the chemical also has definite value for such products. Even blocks of wood containing knots or other defects that would render them useless for woodenware without treatment were successfully turned, shaped, and finished when stabilized with PEG. Woodenware was in fact made successfully from log slabs and large limbs—material ordinarily avoided for such products. The bowls were carved to roughly their finished dimensions, immersed in PEG solution, dried to the very low level of 6 percent moisture content, sanded to final dimensions, and finished.

Wood Identification Service

Another new record was set during 1962 when 709 requests for wood identification service were

received from persons, firms, and public agencies other than the Forest Service. This compares with 707 the previous year. The number of specimens received in 1962 for identification totaled 2,658, of which 1,228 were of foreign origin. Inquiries again came from many sources such as the Bureau of Customs, museums, hobbyists, and collectors of antiques as well as from business firms.

In at least one case, wood anatomy played a deciding role in the proper botanical identification of a newly discovered species from Peten, Guatemala. Study of its wood structure established that the tree was a hitherto unknown species of the *Elaeocarpaceae* family rather than another in which taxonomists had tentatively placed it. It was subsequently named *Petenaea cordata.*

M 123 118

Wood specimen being examined by Dr. B. F. Kukachka was unearthed during paleontological excavations in Oklahoma mammoth beds. Estimated to be 10,100 years old by radioactive C_{14} technique, wood crumbled badly (pieces at right) until treated with polyethylene glycol. Wood structure was characteristic of elm.

M 123 122

Dr. Robert Koeppen regulates device for sharpening microtome blade used to cut wood specimens for microscopic study of wood structure.

WOOD ENGINEERING RESEARCH

A major object of wood engineering research is to develop all knowledge of the mechanical properties of wood and wood-base materials needed to attain their full use potential. The research program encompasses both fundamental investigations of the behavior of wood under various load and environmental conditions and applied studies to establish principles that can be projected into full-scale industrial programs.

Typical of the diversity of studies that span this range are an investigation into the effects of prestressing with steel cable on fundamental properties of glued laminated beams and an evaluation of stressed-skin plywood wall panels that had been in a prototype prefabricated house for 25 years.

Much of the work is closely followed by industry and government agencies because of its direct applicability to problems in housing, packaging, and heavy construction. Requests for assistance and advice are frequent. The Federal Housing Administration, for example, was given information for several Materials Releases on particle board products that helped to provide for effective use of these industry products in housing. Review and comment were given on proposals submitted to the Area Redevelopment Administration for new production facilities. Factual and objective interpretations were furnished FHA and the American Lumber Standards Committee regarding proposed new industry standards on sizes and moisture content of lumber, uniform grades for boards and dimension lumber for light frame construction, and simplified joist and rafter span tables for housing.

Cooperative research on engineering problems financed by industry was highlighted by a fundamental investigation of the properties of hardboard, supported in part by the National Hardboard Association, and a broadscale study of double-wall corrugated fiberboard containers being conducted with the aid of the Fibre Box Association and the Air Force.

Basic Engineering Properties

The re-evaluation of the strength of white fir begun in 1961 was extended to western hemlock during 1962. This work is another phase of the quality assessment of standing timber by means of increment cores described under Wood Quality Research.

As with white fir, alternate logs from the same western hemlock trees were sent to FPL and the Tacoma, Wash., laboratory of the Douglas Fir Plywood Association. DFPA, one of the supporters of the overall western timber quality census, is conducting experiments on the strength of plywood made from veneer of those logs to find a correlation between FPL data on strength of clear wood and those on the strength of plywood.

Data on white fir *(Abies concolor)* from two locations in California and two in Oregon show that, for green wood, the specific gravity and mechanical properties are not greatly different from previous data. There is an increase of about 6 percent in modulus of elasticity, but it is questionable whether this will be enough to materially change the present species groupings with respect to stiffness ratings for joists, rafters, beams, and similar structural parts. Final decision on this and related evaluations must, however, await analysis of data obtained last year on air-dry wood.

Meantime, work is under way on western hemlock from northwestern and southwestern Oregon and central Washington. Data comparable to those obtained for white fir are being obtained on mechanical properties. Further sampling may be done after other phases of the western density survey are completed if results of those phases warrant doing so.

Under separate arrangements with the Pacific Northwest Forest and Range Experiment Station and Oregon State University, random sampling techniques for western hemlock are being studied to find more efficient means of sampling for strength and related properties.

Other basic strength studies included one on redwood and another on several Hawaiian species. Among the Hawaiian woods under study, *Eucalyptus saligna* was shown to have strength properties generally similar to those of the same species grown in Australia and to those of pecan hickory. Silk oak *(Grevillea robusta),* evaluated as a furniture and cabinet wood, exhibited hardness and density generally comparable to those of paper birch but shrank less, being more like black cherry in this property. Nepal alder *(Alnus nepalensis)* is being similarly evaluated and future plans include four other species, mango *(Mangifera indica),* Norfolk-Island-pine *(Araucaria excelsa),* Molucca albizia *(Albizzia moluccana),* and blackbutt eucalyptus *(E. pilularis).* Veneer cutting and machining evaluations are also contemplated. This work is in cooperation with the Pacific Southwest Forest and Range Experiment Station and the State of Hawaii.

Young-growth redwood is now being considered

for use by the industry. From material obtained with the aid of the California Redwood Association, therefore, FPL is evaluating strength properties of sample bolts from trees at several locations in California. Twenty-four bolts were cut from trees on eight plots, three trees per plot, by a random sampling method. Increment cores were taken from those and other trees in the same plots to furnish additional data on the relationship of increment core density to density and properties of the wood.

Closer calculation than hitherto possible for fatigue strength appears as one significant result of a limited study of the effects of knots, drilled holes, and sloping grain in quarter-scale bridge stringers under continuous flexure. Strength-reducing effects of a 1-in-12 slope of grain and knots in the area of maximum tensile strength were shown to be cumulative under such repeated loading. In grading such structural members, this effect can be compensated for by applying a strength ratio that is the product of the strength ratio for slope of grain and that for knots.

An extensive study under way for several years on the fatigue properties of wood in flexure and shear was completed. This work was done in cooperation with the Association of American Railroads.

New information on effects of long-time loading were obtained with small Douglas-fir beams that had carried a constant load for 13 years. Analysis of the data showed that considerable amounts of creep (permanent deformation) occurred when the constant load imposed stress levels 50 percent or more of the short-time strength. The amount of creep was found to depend on the stress level. Findings also indicate that time elapsing until failure occurs may be related to actual loading time in essentially the same manner for cyclic loading as for constant loading.

Useful information about the mechanical behavior of wood under dynamic loading conditions is being obtained from research on the stress-strain behavior of wood in the FPL toughness machine. Load-deflection measurements are being made on Douglas-fir and white fir. Results indicate higher property values under dynamic than static loading, a trend previously found for hardwoods. These findings agree well with earlier data on the effect of rate of deflection on flexural properties.

How fire-retardant treatments affect the physical and mechanical properties is under study to meet design needs resulting from pronounced increases in the use of structural members so treated. In need of such evaluations are building code officials, structural lumber manufacturers, laminators, designers, and manufacturers of treating chemicals. Previous investigations had indicated that treatment causes some decrease in flexural strength properties, but the nature of the effect or the factors primarily responsible remain uncertain.

The comprehensive basic investigation is supported in part by the National Lumber Manufacturers Association, the American Wood-Preservers' Institute, and the American Institute of Timber Construction. Preliminary information indicates that the strength-reducing effect apparently depends upon several factors, including the chemical used, its concentration in the wood, treating conditions, and use conditions. Several chemicals used commercially increase the hygroscopicity, or tendency to absorb moisture, that wood normally has. Wood treated with these chemicals shrinks less at all equilibrium moisture content levels, but species differ. Ponderosa pine, for example, is more hygroscopic when treated than oak, but shrinks more. Other chemicals and treating and exposure conditions will also be investigated for effects on these and other properties in specimens of various sizes.

A computer program was worked out to perform the enormous amount of complex computation necessary for determining how drying stresses in red oak are affected by drying conditions. These stresses develop inside the piece as it shrinks during drying. Since the outer zones dry first, followed by zones successively deeper in the piece, internal shrinkage stresses at any point constantly change as drying proceeds. The nature of these stresses and how they are changed in magnitude and distribution during the course of drying at various temperature and moisture content levels comprises the information being calculated by the computer. So many variables are introduced in the equations used that the program would be impractical without the computer. Ultimately it is hoped to determine temperature and humidity conditions that achieve drying at the fastest practical rate without encountering serious drying degrade in the form of honeycomb, collapse, splitting, and the like.

This computer program is based on mathematical relationships derived for calculating perpendicular-to-grain stresses at any point on the cross section of a drying board. The information needed for those calculations is supplied partly by measurements of thin slices cut from wood at various stages of drying under known conditions, and partly by data on the perpendicular-to-grain mechanical properties of wood at corresponding conditions of temperature and moisture content. Such information has been developed for red oak and is being used in the stress computations. Similar information is being obtained for ponderosa pine.

Physical Properties

Research on the physical properties of wood, other than dimensional changes and stabilization, is concentrated on dielectric and vibration properties that may aid in devising nondestructive methods of evaluating mechanical properties. The two dielectric properties being studied are the dielectric constant and the power loss factor. The dielectric constant is broadly a measure of the polarizability of wood when put in an electric field, while the power loss factor is that fraction of energy stored in the polarized wood that is lost per cycle. These properties were measured in Douglas-fir at three microwave frequencies, 1, 3, and 8.5 gigacycles (10^9 cycles) with the wood at various moisture content levels from the green condition to 6 percent.

At both 1 and 3 gigacycles, dielectric constant and power loss factor decreased with decreasing moisture content. Both were higher parallel to the grain than perpendicular to it in either the radial or tangential direction. Wave distribution patterns at 8.5 gigacycles were anomalous, and require further investigation.

The sound vibrations set up in wood, as when struck with a hammer at one end, offer another approach to nondestructive measurement of certain mechanical properties. The natural frequency of the sound has been well correlated with modulus of elasticity. It is apparently no better than density, however, as a measure of maximum crushing strength, modulus of rupture, shearing strength, or toughness. Correlations with these properties appear to be better at low than at high moisture content levels. Measurements of sound amplitude damping rates yielded similar results.

A slope of grain of 1 in 3 was shown to have a pronounced effect upon the speed of sound through wood, slowing it up twice as much as did straight-grained wood, either green or dry. The effect of slope of grain on internal friction was even more pronounced, however, increasing about 2.5 times in air-dry wood and 4 times in green wood with a slope of 1 in 3 as compared to straight-grained wood. The findings agree generally with the known fact that bending strength drops off faster than stiffness with increasing slope of grain.

Meanwhile, FPL cooperated with two western industry laboratories in evaluation of nondestructive testing machines developed by them. Cooperation was also given the American Society for Testing and Materials in development of an ASTM recommended practice recognizing these nondestructive tests.

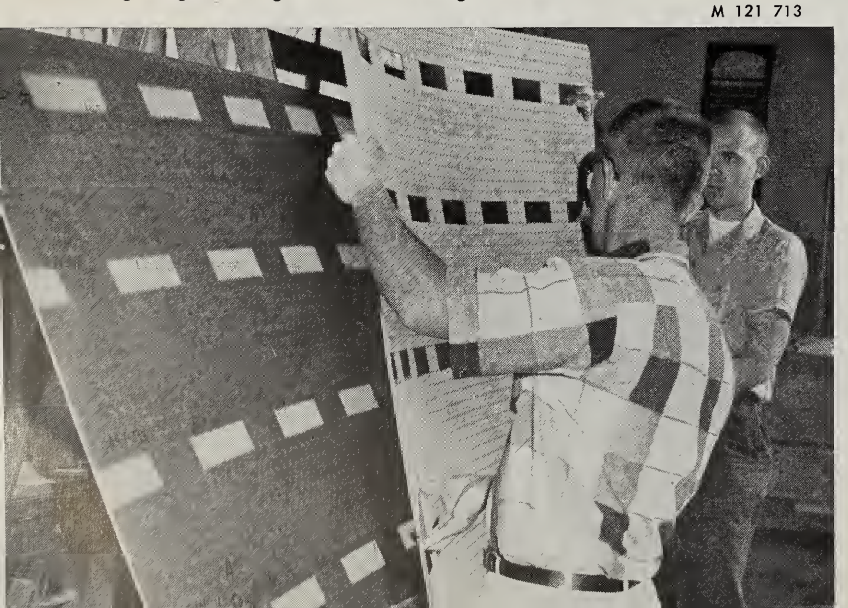
Hardboard Properties

The extensive 4-year investigation of fundamental mechanical properties of hardboards described in the 1961 Annual Report proceeded with material furnished by the cooperator, the American Hardboard Association. To be evaluated are plastic and elastic behavior, effects of duration of stress, fatigue and rate of loading, and time-temperature-moisture content relationships. More efficient strain-measuring apparatus was devised to facilitate this research.

Coordination of commercial standards proposed for several woodbase materials was undertaken, in cooperation with interested industry groups, for the Commodity Standards Division of the U. S. Department of Commerce. Among these will be one for hardboard, one for garage doors built with hardboard panels as the main covering material, one for mat-formed wood particle board, and one for extruded particle board. These new materials have come into extensive use largely on a trial-and-error

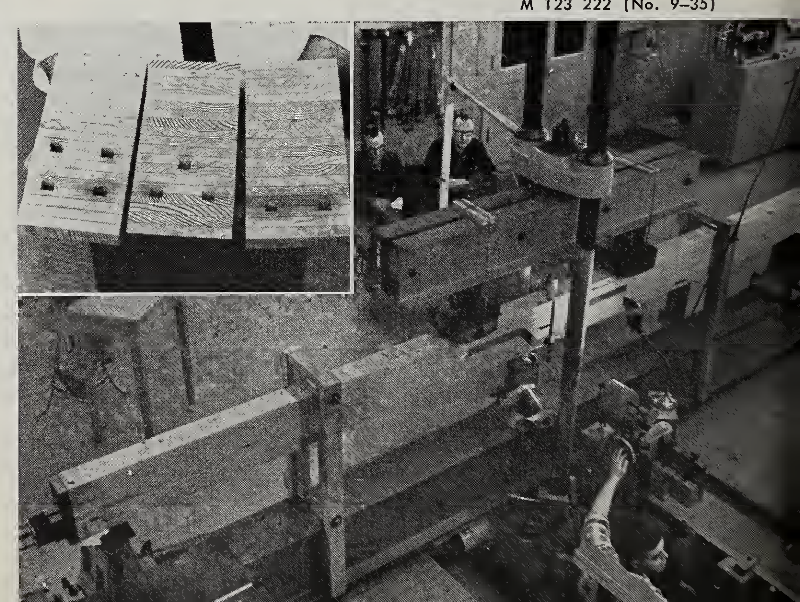
Template method used to obtain matching specimens from different sheets of hardboard in research aimed at developing engineering data for design criteria.

M 121 713



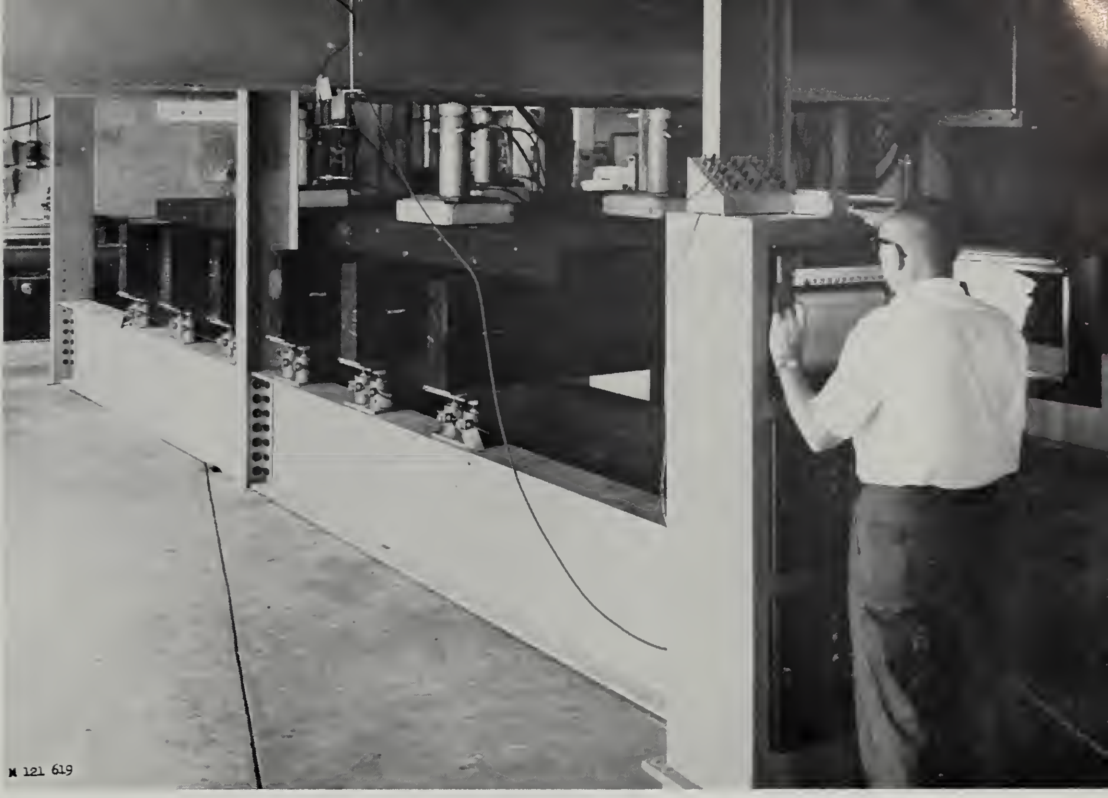
Laminated wood beam prestressed with wire cables extending through lower portion is under bending load to measure how much load-carrying capacity is increased. Inset shows several patterns of cable passages tried.

M 123 222 (No. 9–35)



M 121 619

Full-scale wood highway bridge built indoors to study structural principles. Ends of stringers are mounted on pairs of load cells to measure distribution of loads put on deck above by hydraulic pistons simulating truck wheels.



basis. Commercial standards would provide minimum quality and size provisions, methods for testing strength and other properties, and related information necessary for more effective use of these materials in engineered structures.

Laminated Construction

A new concept for prestressing glued laminated wood beams with steel wire cables received preliminary evaluation and was considered to offer promise of eventually increasing allowable loads by substantial margins. Limited studies showed that beams so prestressed can carry larger loads than matching control beams not prestressed, and that a more reliable prediction of ultimate load can be made for a prestressed beam. The data indicated that greater increases in strength resulted from use of the reinforcing steel strands in the lower structural grades of beams.

The prestressing was accomplished by applying a tension force to the steel strands inserted in prepared holes in the tension portion of the beam. This induced bow in the beam, in effect putting under compressive stress the portion of the beam that in service would be under tensile stress. Under service load, therefore, the prestressed beam theoretically can carry a higher load. In effect, an increase in allowable load is possible because of additional load needed to flatten the prestressed beam.

Research is being continued to investigate this effect further and possibly develop methods of design for commercial prestressed laminated beams. Major benefit could accrue to the laminating industry.

A design study of multiple-bolt joints in laminated structural members, such as the lower chords of trusses, yielded data in general agreement with design values for multiple-bolt joints in solid wood as presented in the National Design Specifications. Realistic design procedures for laminated lower-chord truss members are being worked out on this basis.

An investigation of a possible corrosion hazard to nails and other metal fastenings resulting from use of fire-retardant chemicals in laminated beams was begun and is projected over 4 years. Nails are commonly used to fasten flooring, roof decking, ceiling sheet materials, and other coverage to laminated beams. Several types of nails, including common-wire, aluminum, annular-grooved, and cement-coated, are included in the corrosion study. Nail-withdrawal tests are made periodically. Early results show an increase in withdrawal resistance due to corrosion. Continued corrosion, however, would of course weaken the nails seriously.

Structural Investigations

Structural research at FPL currently includes investigations of design and construction features of railroad and highway bridges, housing, and Forest Service fire lookout towers. Of these, the housing work is as always most extensive in scope. It ranges from continuing long-time analyses of the stressed-skin system of panelized housing FPL pioneered 25 years ago to new concepts for unitized structural systems, evaluations of adhesive uses in new types of construction, and studies aimed at more watertight constructions.

The highway bridge design study, conducted in

cooperation with the Forest Service Division of Engineering, was featured by evaluations of full-scale bridges with spans up to 28 feet in the Laboratory. Key elements in these structures were the wood stringers, timbers 8 by 16 or 6 by 18 inches in cross section. Wood decking was nailed down across the tops of the stringers, and pairs of hydraulic pistons simulating truck wheels imposed loads equivalent to axle loads. Distribution of these loads to the various stringers was measured by electronic load cells. Loads up to 100 tons were applied.

Loads were found to be more uniformly distributed among the stringers than is recognized in bridge design formulas now commonly used. Arrangement and nailing of the 2- by 6-inch decking appeared to have little effect on load distribution. Loadings that caused bending failure in the stringers were great enough to assure at least adequate margins of safety, provided the timbers used have been carefully graded according to recognized principles of structural grading.

More efficient design criteria for calculating distribution of wheel loads will be sought through correlation of the experimental findings with theoretical analyses yet to be made.

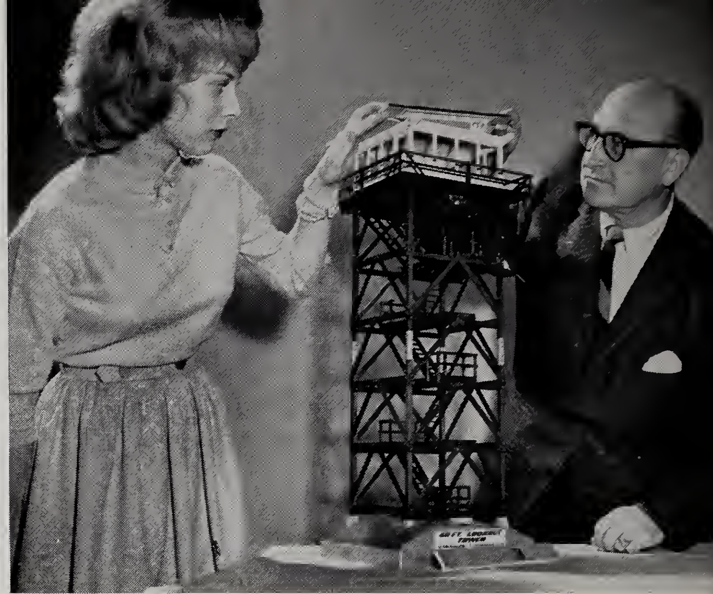
Suggestions for improvements in design of wood railroad bridges were incorporated in a report summarizing results of fatigue studies of quarter-scale stringers of Dougas-fir and southern pine. The report points out that fatigue considerations are especially important in the shear design of stringers. Reconsideration of shear design practices is suggested because preservative treatment has extended the life of stringers so greatly that fatigue becomes critically important.

Full-scale railroad bridge stringers of glued-laminated construction are being evaluated by the Association of American Railroads, and FPL is cooperating in these studies. The importance of fatigue induced by repeated loading is being borne out in these studies.

Because of continued limited demand for hardwood structural timbers in railroad bridges, FPL furnished the National Hardwood Lumber Association with provisions that permit stress ratings for one of its timber grades. The association had previously dropped structural grading of hardwoods. Renewed interest in structural grades of hardwood timbers has prompted the development of a simplified system of structural grades by FPL at the association's request, for possible incorporation in NHLA grading rules.

Fire Lookout Towers

There may be a "new look" among Forest Service fire lookout towers in the near future. Two new concepts have been suggested by FPL design engineers. One is a unitized construction utilizing



M 123 486

FPL Engineer Otto C. Heyer demonstrates application of FPL's stressed-skin panel construction principle in cab roof for newly designed fire lookout tower to Secretary Sandra Gibson. Tower designed by Gray and Evans, consulting engineers at Seattle, Wash., can be built to heights of 40 to 100 feet.

precut, interchangeable wood members for the structural framing and a stressed-skin, panelized, observation cab and cab platform. The other, as yet only an unexplored idea, would be a cylinder of honey-comb core sandwich construction capped by a circular observation cab.

The unitized timber and stressed-skin structure reached the engineering design stage during 1962, when a Seattle firm of engineers, Gray and Evans, was given a design contract. An experimental tower is to be built by the Forest Service in the Pacific Northwest. The designs decided upon consist of structural units 8 feet high and 14 feet square, one for towers 8 to 40 feet high and one for towers 48 to 96 feet high. Structural timbers are precut to exact size and bored for bolts and timber connectors used in assembly. All cutting and boring are done before the timbers are preservative treated, in order that untreated wood beyond the penetrated zone need not be exposed to decay fungi during assembly, erection, or use. Interchangeability of parts and special bracing are expected to make for more economical and sturdier construction.

Atop this structural tower is laid a 20-foot-square platform consisting of five 4- by 20-foot stressed-skin plywood panels. These can be lowered in place by helicopter in areas difficult to reach by land. The preassembled cab would also be transported and lowered into place by helicopter in such locations.

It is hoped that the sandwich-type cylindrical tower can reach engineering design stages in the near future. It would have great advantages from the standpoint of light weight, permitting its transport by helicopter to any desired location. The

cylindrical design is also expected to provide greater structural stability against wind forces.

Housing Research

A landmark in housing research was appropriately recognized in late 1962 when several stressed-skin wall panels were removed from one of FPL's two prototype prefabricated houses for re-evaluation exactly 25 years to the month from the time they had been installed. The two houses, in continuous use ever since, have served as models for much factory-built housing.

Bending strength of the wall panels was found to be virtually unaffected by the quarter century of service. Joints between panels were clean and free of deterioration. Specimens of the nail-glued joints between plywood covers and wood framework are to be given further evaluation for possible adhesive deterioration.

The panels were replaced with new ones in which a contact adhesive was used to bond the plywood skins to the framework. Pressure was applied with a roller press through which the panels were passed. Such adhesives were not available when the original panels were made.

Similar periodic checks are being made on sandwich panels with paper honeycomb cores and facings of plywood, hardboard, and other sheet materials, which were fabricated and incorporated in the walls, floor, and roof of a test structure in 1937.

The wide range of seviceability of modern glues has prompted investigation of their more extensive use in conventional house construction. A study initiated in 1962 involves the strength and rigidity of glued joints bonding wood to plywood. Effects of time, loading environment, and normal atmospheric conditions are being noted. Solid wood parts of the joints were installed at several moisture content levels to ascertain effects of shrinkage or swelling on the glue bonds. The joints under study are typical of those made in roof trusses with plywood gusset plates.

How well water-repellent preservative can resist penetration of rainwater through joints between boards of drop siding has been under investigation for several years in panels exposed outdoors. The siding had been dipped in the repellent before being installed. Control panels, identical except that they were not treated, are also under observation. Sidings used are southern pine, Douglas-fir, and western redcedar, all 1 by 6's. Indications are that a worthwhile barrier against rainwater is provided by the treatment in laps and the joints at board ends. Paint appears to remain in good condition longer on the treated siding.

Wood Pole Specification

More efficient use of wood utility poles, some 5 million of which are produced each year, is promised in revisions of the specifications for poles promulgated by the American Standards Association. These revisions are largely based on an extensive pole-strength research program conducted by FPL in cooperation with ASTM and pole suppliers and users over several years. Laboratory specialists have worked closely with ASA's Sectional Committee 05 on Wood Poles in considering results of that program and related information. A special analysis of fiber stress data was prepared for the committee. Substantial agreement appears to have been reached on the proposed revisions to the specifications.

Packaging Research

Research on packaging at FPL has long had substantial military support, and more than one-half of it continues to be done primarily for various branches of the Department of Defense. Some of this work, of course, has much broader application. For example, a current study of double-wall corrugated containers supported by the Air Force may lead to greater allowable loads under freight classification rules. On the other hand, another assignment involving standardization of some 1,400 military packaging test procedures is of specific interest only to military agencies.

Research under way during 1962 included studies of fiberboard containers, cushioning materials, pallets, and wood boxes.

The fiberboard container has come into such widespread use that research involving it attracts much industrial attention. At FPL, two industry advisory committees are active in a consulting capacity, one comprised of container producers and the other of users who represent a $200 million annual market. At a meeting at FPL in 1962, the user committee compiled a list of 21 problems needing solution. Research is under way on three of these:

(1) Improvement of stacking strength at high humidities.

(2) Improved and simplified methods of predicting stacking strength of filled containers.

(3) Development of a method of determining the tensile strength of corrugated board.

A study is in progress on a method of improving container stacking strength that has much promise under conditions of high humidity in warehouses. The problem, of course, results from modern materials handling methods and machines that permit piling boxes or pallet loads of boxes one atop another to great heights in warehouses. The method under study involves incorporating 1/64-inch gum veneer into the assembly of flat and cor-

rugated paperboard sheets of which conventional corrugated fiberboard is comprised. The veneer, of course, is much less susceptible to the weakening effects of high humidity than is the fiberboard.

This study is a cooperative undertaking with the Air Force and a manufacturer. The veneer is covered on both sides with paper, and then a layer of single-face corrugated board is glued to each side. From this the container is fabricated by conventional methods. Preliminary evaluations have shown good stacking strength and stiffness at high humidities.

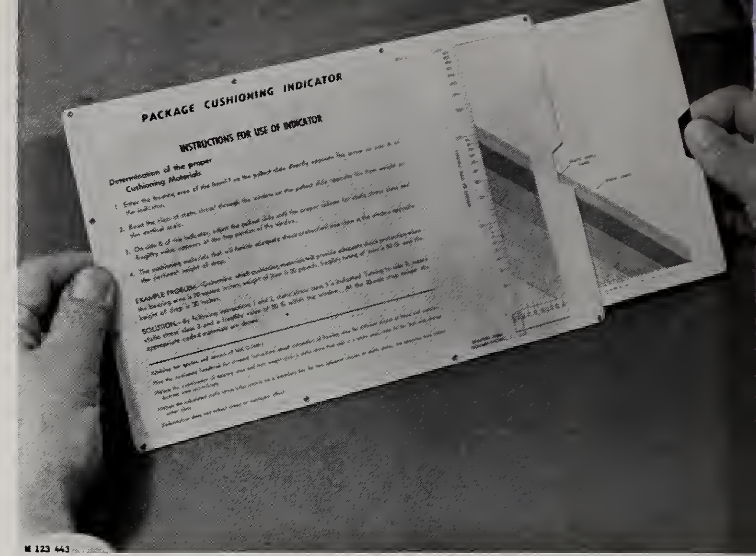
The growing need for better design criteria to tailor corrugated containers to specific uses calls for development of more meaningful tests of paperboard and corrugated fiberboard. The bursting strength test now universally relied on correlates with compression strength and rough handling characteristics of corrugated containers in only the loosest terms. To provide more accurate means of evaluating the materials, studies are under way on the relation of container strength to basic properties of the combined board, the stiffness factor (EI), and ultimate crushing strength as determined from short column tests. Simple procedures for measuring these properties and flute height are being checked for reproducibility and show considerable promise. More effective board classification appears within reach by these means.

An extensive project supported by the Air Force and the Fibre Box Association was carried through the testing stage to investigate validity of present freight classification load limits for double-wall corrugated containers with 500- and 600-pound Mullen test ratings. Presently these containers are limited to 140-pound and 160-pound loads, respectively. Analysis is being made of data from tests of more than 1,000 of these containers in top-to-bottom compression and from components of the containers. Design criteria applicable to all types of double-wall corrugated containers are being developed. Preliminary analysis indicates that maximum loads of the containers tested can be increased.

Cushioning

The manuscript for a handbook on package cushioning design, the outgrowth of years of research in this field, was prepared for the Air Force. When published, this document will provide the Department of Defense and other government agencies, as well as industry, with means of applying sound engineering principles to problems of cushioning for a wide range of machinery, equipment, and instruments in need of such protection during transit.

To facilitate use of various cushioning materials, a cushioning selection indicator was devised for the Air Force. The indicator is based upon results of



M 123 443

Indicator devised for quick determination of cushioning needs in packaging.

dynamic compression evaluations of cushioning materials. Thickness and kind of material needed can be readily calculated.

To make corrugated fiberboard a more acceptable cushioning material, research is under way to develop design methods for its engineered use comparable to those previously devised for other cushionings. Equipment previously developed for the dynamic evaluation of other materials under Air Force cooperative programs is being tried out and modified as necessary to evaluate performance of fiberboard pads. A loading head has been devised that permits discrimination between wanted data and distortions that previously interfered with fiberboard evaluation. A linear deadweight accelerometer calibration capable of applying square-wave and half-wave acceleration pulses has been built. Evaluation work is expected to be begun during 1963.

Pallets

The extensive use made of pallets by industry for the handling of packages with forklift trucks and other machinery has provided a sizable outlet for much lumber, notably hardwoods of low quality. The pallet is a platform on which a number of packages can be mounted, and is so designed that lifting forks and other devices can be conveniently slipped under or into it for transport purposes.

The hard use given pallets makes good design essential. Evaluation procedures and performance requirements have been developed from FPL research for review and consideration by industry and for possible adoption as a standard promulgated by the American Standards Association. Evaluations by the 14-foot drum test, the corner drop test, and a bending stiffness test are proposed.

An efficient design for a sturdy pallet made of lightweight aspen wood was developed and immediately aroused commercial interest in areas where this species is plentiful, notably the Lake States and

the central Rocky Mountains. To compensate for its light weight, boards of this species are used in full inch thickness rather than the 25/32 or $\frac{3}{4}$ inch to which such lumber is normally cut and dressed. Deck boards were fastened to stringers with 3-inch nails spirally grooved from hardened steel, rather than the heavier gage $2\frac{1}{2}$-inch nails normally used. Less splitting resulted, and the longer nails helped offset the relatively low nail-holding power of aspen as compared to that of the heavy hardwoods. Evaluations in the laboratory promise good service, and cost appears competitive.

New automated systems for loading and unloading cans from pallets led to a study for the Can Manufacturers Institute of pallet designs most suitable for the purpose. Standardization on one design is being sought by the Institute. Four types were evaluated and the results forwarded to the Institute with recommendations for design improvements.

Research was continued on the use of adhesives and mastics instead of nails to fasten parts of wood fruit and vegetable boxes together. Problems being worked on include that of providing some resiliency in containers assembled with glues to increase resistance to rough handling, and ways of reducing the time required to cure the adhesive.

M 123 435

Aspen pallet tumbling in 14-foot rotary drum that simulates rough handling.

SOLID WOOD PRODUCTS RESEARCH

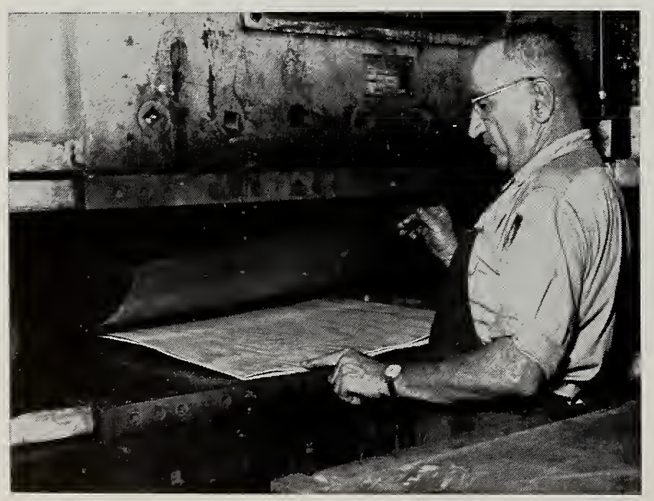
Solid wood products are by definition those in which wood retains its physical identity. They range from rough lumber to veneer and plywood, glued laminated wood, and particle board. Research on these products, therefore, encompasses not only their production and various fabrication and service-life problems inherent in their use, but related investigations aimed at improving their serviceability and appearance—notably gluing, preservative, fire-retardant, and finishing treatments. These, in turn, involve chemical, pathological, entomological, and bacteriological studies, and studies of adhesives, paints, preservatives, fire retardants, and fungi, insects, and bacteria that attack wood.

Solid wood products research went forward during 1962 under eight main categories: Glues and gluing processes; machining and veneer cutting; wood drying; wood finishing; fire performance; environmental effects; preservative development and treating processes; and wood-attacking fungi and insects.

Southern Pine Plywood

A chain of circumstances that brought years of FPL research to fruition at a time when silvicultural and economic conditions had turned exceptionally favorable set the stage during 1962 for the early birth of a promising new southern pine plywood industry.

Strong interest among several leading industrial concerns by year's end firmly supported estimates that during 1963 this industry would become a reality. Indications were that investments in plant and equipment will provide a market for southern pine peeler-quality logs totaling 75 to 100 million board feet annually in producing $12 to $15 million worth of plywood. Such a production level would require a $10 million investment in plant and equipment and furnish direct employment to 750 millworkers.



M 122 563

Southern pine veneers in hot press used for plywood experiments.

Expansion of this industry in future years would, of course, substantially increase these initial employment and investment figures, simultaneously broadening the market for much high-quality southern pine grown on plantations under good silvicultural conditions.

The technological and economic conditions that led to this development have undergone a complete about-face since as recently as 1945. Advances in veneer and plywood research made during the past several years at FPL have been accompanied by marked changes in conditions in the western softwood plywood industry as well as in the South.

At the end of World II, there were still substantial supplies of high-quality peeler timber in the forests supplying the West Coast industry, while there was little timber of comparable quality in the South. Since then, however, increasing production has led to technological practices that made progressively smaller and lower quality timber suitable for western softwood plywood. At the same time, new supplies of high-quality timber were maturing on southern pine plantations, for utilization of which the new western small-log technology was well adapted. This southern pine timber, in fact, was approaching sawlog size at a time when lumber markets for such high-quality material were shrinking.

Recognizing these converging trends and the opportunities they represented, FPL scientists pushed research on technical problems that had thwarted earlier efforts to produce plywood from southern pine. Early results indicated that a paneling grade of plywood could be manufactured by slicing southern pine veneer logs for the faces and using veneer cut on a rotary lathe for interior plies.

Continued research turned up methods of selecting and heating logs, cutting and drying the veneer, and gluing veneer together to make sheathing-grade plywood entirely from rotary-cut veneer. This is the grade of softwood plywood now produced in largest volume. It is widely used for subflooring and wall and roof sheathing of houses and other wood-frame structures.

Using this technical information, several concerns last year conducted pilot studies that were successful enough from the technical standpoint to warrant serious consideration of commercial produc-

tion. At a mid-November conference at FPL, an industry committee initiated steps to prepare a commercial standard for southern pine plywood. Contributing to the success of this conference was a rush analysis of specific gravity data gathered as part of the southern pine timber density survey described under Wood Quality Research. This analysis provided needed information about the strength of southern pine timber otherwise meeting quality requirements for plywood. Aid was also extended the industry on requirements for structurally sound grades of plywood. At year's end the draft for a Commercial Standard was being readied by an industry committee for consideration by the U. S. Department of Commerce preliminary to submission to the industry.

Glues and Glued Products

The development of new and improved glued wood products hinges to a great extent upon advances in adhesives and gluing technology. Among important aspects of FPL research in this area during 1962 were studies aimed at modifying certain mechanical properties of glued joints, notably through the use of nonrigid adhesives. The theory behind this work is that, if an adhesive can undergo a certain amount of deformation, it can absorb differential stresses developed in the wood members it holds together. Such stresses develop, for example, if two wood members are glued together so that the grain of one is at an angle to that of the other; shrinkage and swelling can induce opposing stresses that conceivably could fracture a rigid glue, with resultant failure of the joint. A less rigid glue—preferably one with a modulus of rigidity approximating that of the wood used—could be expected to deform sufficiently to absorb some of the conflicting stresses developed in the two wood members.

Three adhesives known to have widely differing moduli of rigidity were used to evaluate the theory with a series of glue joints between plywood and softwood lumber typical of those in trusses with plywood gusset plates. In these joints, of course, the lumber would undergo greater change in width than the plywood when exposed to conditions inducing swelling and shrinking. One of the adhesives chosen was an experimental epoxy-polysulfide that had a modulus of rigidity about the same as that of the lumber; the second was compounded of similar resins to have a modulus about one-third that of the lumber; and the third was a resorcinol glue with a modulus 10 times that of the lumber.

Exposure to severe cyclic changes from dry to humid conditions provided substantial confirmation of this theory. Joints made with the adhesive most closely approximating the wood in rigidity sustained least loss in joint strength. Additional research is needed to adequately evaluate the theory. On the basis of the present findings, studies are also continuing on adhesives that can deform when subjected to opposing stresses induced in the wood members they join.

Gluing Fire-Retardant-Treated Wood

Continuing research on the gluing of wood treated with fire retardants uncovered two possible chemical causes of difficulties in producing strong joints in such wood with resorcinol and phenol-resorcinol adhesives. These glues are being concentrated upon in this investigation because of their superior heat resistance.

Chemical interaction between the fire retardants and the adhesive is now thought to be due either to an interaction of ammonium salts in the fire retardant with free formaldehyde in the resin, or to an acid-alkali balance at the wood surface that interferes with hardening of the glue. The formaldehyde-ammonia reaction is considered the more likely cause of difficulty. Work is continuing on the formulation of resorcinols with enough formaldehyde both to satisfy the ammonium salts and complete the glue-curing action.

New Adhesives

During 1962, close relations with adhesive manufacturers that had been established with the 1960 FPL Adhesives Symposium continued to yield useful returns in the development of improved adhesives for different wood-bonding uses.

One promising formulation, a contact-bonding type, was tried out for manufacture of stressed-cover house panels in a roller press that applied pressure for only an instant. The panels, with plywood and hardboard faces, were then installed in an experimental house for long-time durability evaluations. These panels replaced nail-glued ones that had been made when the house was originally erected in 1937 as the first prefabricated house designed according to FPL's stressed-cover principle. The original panels were evaluated for strength after 25 years of service; results are described under Wood Engineering Research.

Another promising new industry-developed adhesive now under long-term durability study is a thermosetting vinyl emulsion. This formulation not only has the convenience of its general type for use in finger-jointed lumber and other glued wood assemblies, but has resistance in the boil-cycle test commonly used to evaluate exterior-type plywood.

Experiments with condensation products of alkaline bark extracts and formaldehyde yielded adhesives that were neither so strong nor so water resistant as phenol or resorcinol resin glues. Their

possibilities as extenders in such glues, moreover, appear limited by recent drops in the price of phenol. Commercial use of such condensates for adhesives, therefore, appears to depend upon development of more fundamental knowledge of the chemistry of these extracts, work on which is noted under Wood Chemistry Research.

Finger Joints in Lumber

So-called "finger" joints consisting of long interlocking serrations at the ends of pieces of lumber were experimentally produced that had tensile strength in the area of 6,000 to 10,000 pounds per square inch in dense, straight-grained Douglas-fir. Strength values in the lower range were obtained with fingers only ⅝ to ¾ inch long; the top of the range was attained with fingers 1¾ inches long or longer. These strengths are considered adequate for requirements in dimension lumber used for certain applications in structural framing. Research is continuing on suitable adhesives and gluing conditions as well as joint machining requirements.

Building Components

An urgent marketing situation at Arizona and New Mexico ponderosa pine sawmills, where apparently unsalable low-grade boards had been accumulating for some time, prompted a large-scale investigation of the possibilities of making various building components from this lumber. Material sent from southwestern mills to FPL for the study included low-quality logs, low-grade boards, and shavings.

With the cooperation of the Rocky Mountain Forest and Range Experiment Station, which assigned a technologist to the work, a number of products were made, several of which were entirely new and novel. Among these were vertically laminated members made by gluing boards together to serve as floor or roof beams. Boards were also used to make several types of house siding by covering the knots and other defects on one or both sides with resin-treated kraft, parchment paper, or vulcanized fiber. A flexible type of flooring, utilizing boards as the base for hardwood veneer surfaces, demonstrated another product for which the knotty ponderosa pine boards were considered suitable.

Logs were also cut into veneer of two thicknesses. The thicker veneer was used as faces for a subflooring panel in which boards were used as the core material. The thinner veneer was glued together into three-ply plywood for use as underlayment for resilient-type finish floors.

Shavings and flakes were converted into four types of particle board suitable for wall paneling and for concealed cabinet and furniture parts. Chips were bonded together to form the central layer of a three-ply particle board 2 inches thick, conventional flakes being used for the outer layers. This thick board was designed for use as door cores, interior partition, and roof decking.

Information needed to make and utilize all products was reported to the Southwestern Pine Association and interested lumbermen. Taken together, these products comprise all essential structural components of a house shell. All, moreover, can be factory produced for rapid assembly on site.

Slicewood

The discovery during 1962 that, when flitches—rectangular sections of logs—are first compressed, they can be sliced into material relatively free from knife checks promises to overcome one of the most serious technical handicaps to the production of commercial Slicewood—the name given to material cut on a veneer slicer in thicknesses from ¼ to ½ inch.

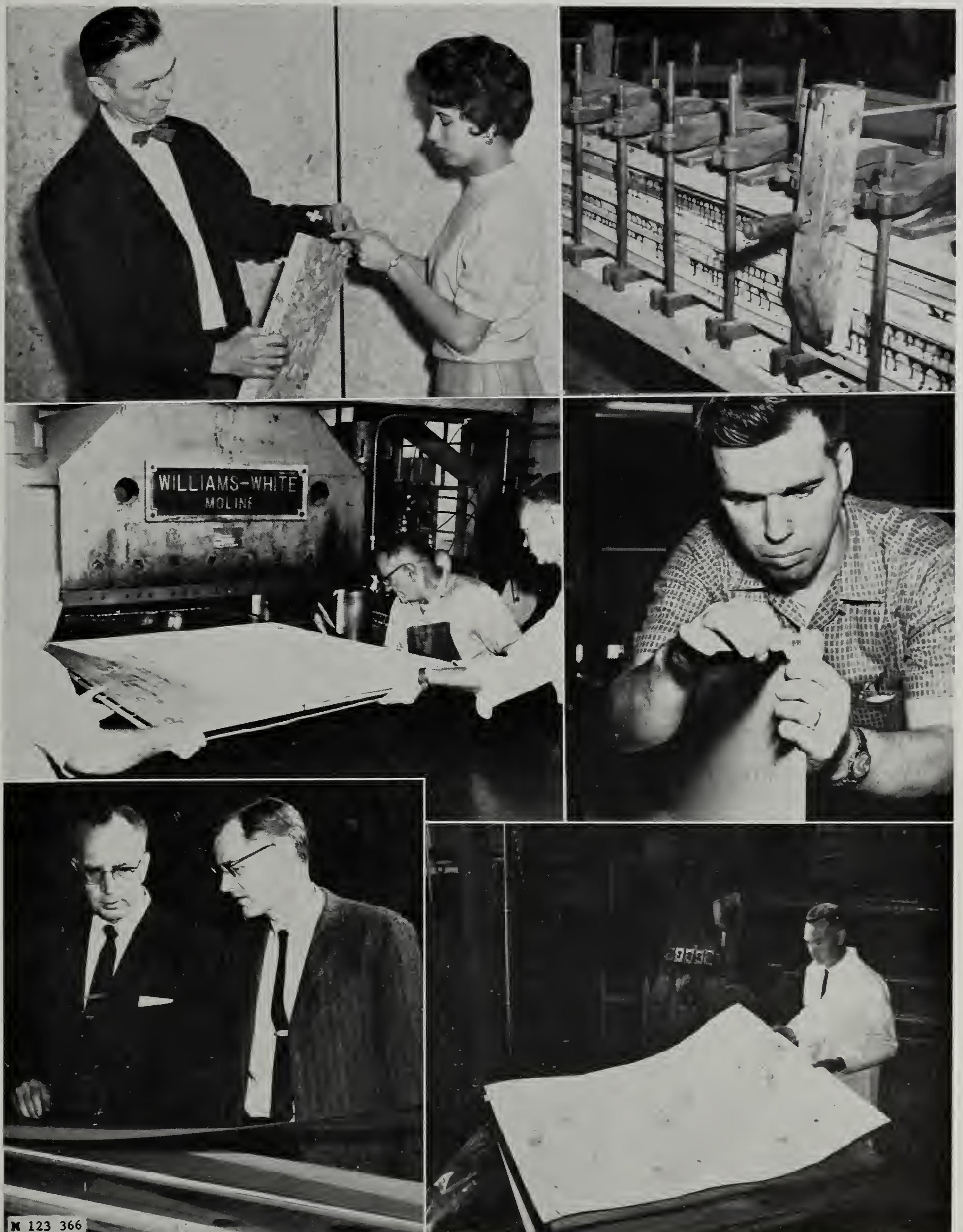
The flexibility known to be induced in wood when compressed prompted the compression experiment with yellow-poplar flitches. Even though flitches recovered almost completely from compression of up to 50 percent after release of pressure, they yielded ¼-inch Slicewood entirely free of knife checks. It is thought that the residual compression in the flitches was enough to prevent formation of these hairlike cracks when the flitch was pressed against the nosebar of the slicer.

At year's end, plans were being drawn for a new experimental slicer designed for production of thick Slicewood to replace the conventional veneer slicer on which experiments have thus far been conducted.

Machining with Light and Water Jets

During 1962 a grant of funds was made to the University of Michigan to support two machining investigations by a candidate for a Ph.D. degree in wood technology. One was an exploratory study of the potential of a device incorporating a recently discovered principle of physics known as "light amplification by stimulated emission of radiation." The device takes its name, laser, from the first letters of the quoted words.

Available lasers in the power range necessary for cutting wood require a synthetic ruby as the medium for stimulating and amplifying light. Lasers of this type thus far developed produce light in pulses rather than steady beams. Chromium atoms in the ruby give off photons of light when excited by a high-voltage current in a xenon flash tube coiled about the ruby. This radiation builds up within the ruby until it bursts from one end as a red flash of highly unidirectional light some 50 microseconds in duration. This pulse can be focused



M 123 336

FPL developmental research produced this variety of products from low-quality ponderosa pine. Upper left, Engineer Bruce Heebink demonstrates to Secretary Judy Noll a spline joint for 2-inch, three-layer particle board made of chips and flakes for partition wall in background. Upper right, clamps compress low-quality boards together as glue cures in laminated floor and roof beams. Center left, lumber-core subflooring is placed in press for gluing. Center right, Technologist Charles Gatchell checks thickness of resawn ponderosa pine siding with paper overlays. Lower right, Forest Service Chief Edward P. Cliff observes overlaying of low-quality boards as Dr. H. O. Fleischer, chief of FPL's solid wood products research, explains process. Lower right, Rocky Mountain Station Technologist Roland Barger examines veneer cut from low-quality ponderosa pine logs at FPL.

with optical lenses. The effect on wood is to vaporize it at the point focused upon to a depth of 1/32 to 1/16 inch. Repeated pulses deepen the hole.

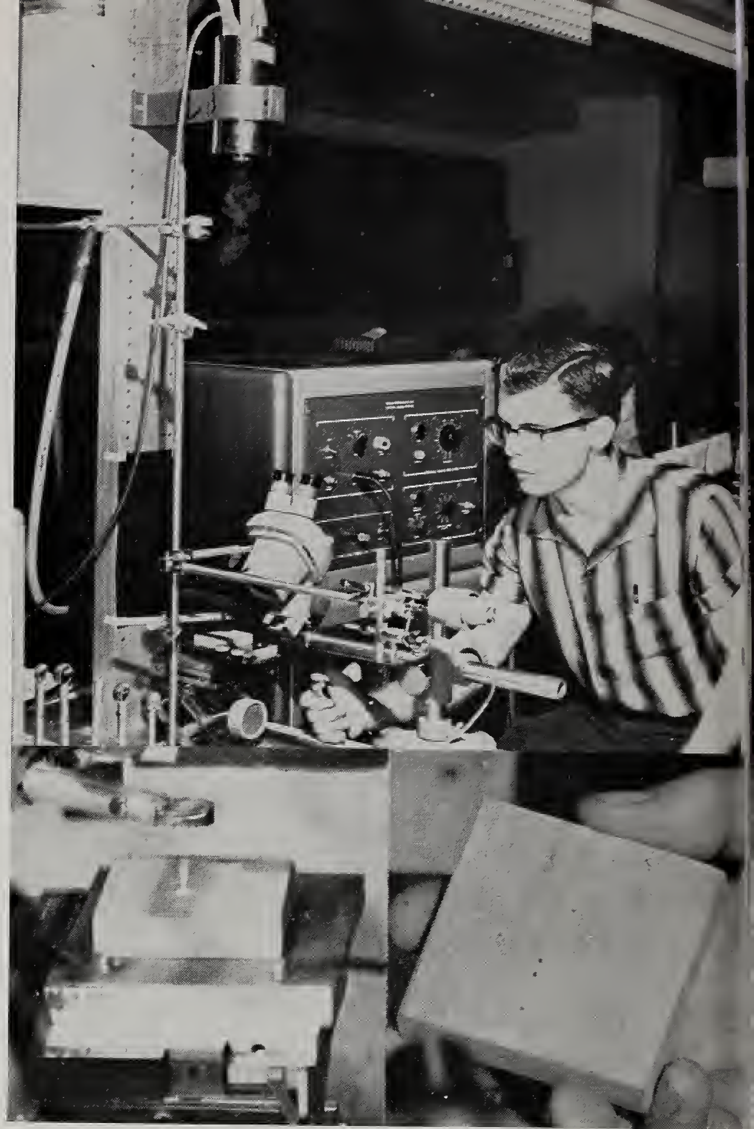
When a constant-beam laser of comparable power becomes available, it may prove useful for cutting and machining wood, since it could hypothetically penetrate a 30-inch log in less than 1/20 second.

With the completion of the laser study, a more detailed investigation was begun of the utility of high-powered water jets for cutting and machining wood. Work on this technique was just getting under way during the last months of 1962 with jets in the power range of 50,000 pounds per square inch and orifices 0.001 to 0.010 inch in diameter.

Particle Board

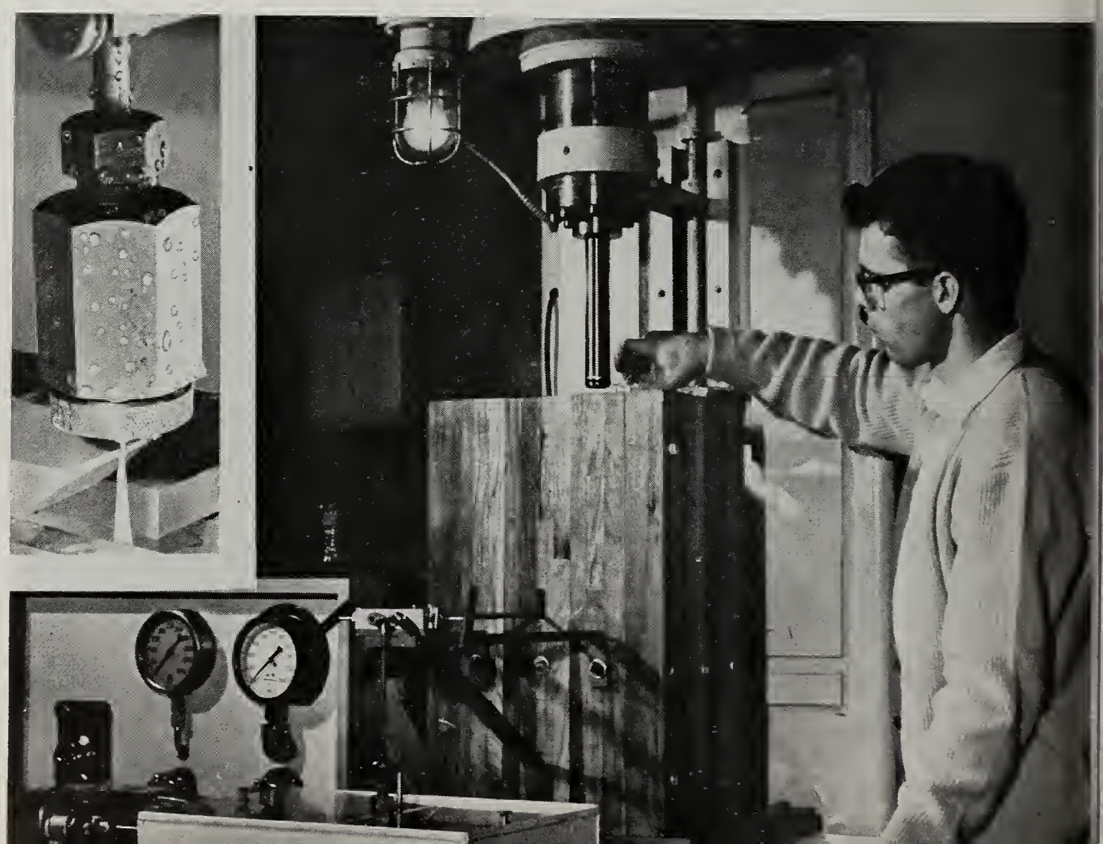
A treatment was developed that removes the inherent tendency of flat-pressed particle board to "spring back"—that is, to regain much of its original thickness—after swelling during exposure to rain or high humidity. This tendency has been a major drawback to outdoor use of such particle board, since swelling tends to roughen the surface as well as pull nailheads. The cause is not well understood, although board made of lightweight woods appears in general to spring back more than that made of dense species.

The treatment for removing springback consists of steaming the board at saturation pressure and approximately 300° F. while it is still in the hot press. The steam and heat induce plastic flow within the board, thereby relieving compressive stresses in the particles that are thought to be responsible for springback. Normal shrinking and swelling tentencies of the wood particles are not greatly affected. The treatment may also prove useful for other compressed solid wood products.



M 123 367

Laser equipment used by Eugene Bryan at University of Michigan to drill holes in hard maple with enormously amplified pulses of light in study supported by FPL grant. Lower left, light beam is focused by lens on wood block. Lower right, pinpoint holes in block were caused by laser beam.



M 123 255

Water-jet equipment used in wood-cutting experiments conducted at University of Michigan with FPL grant. Water under 50,000 pounds of pressure per square inch passes through jet (inset) with orifices 0.001 to 0.010 inch in diameter at speeds up to 3,000 feet per second.

Experimental work extending over several years was concluded on the effects of typical and modified planer shavings on particle board properties. In general, the findings indicate that a modified planer head designed to produce shavings of best form for particle board is suitable for typical products of a high-speed planer-matcher, such as studs, on which some surface roughness is not objectionable. For products requiring the best planing, however, a conventional planer head is probably necessary, at least for the finish cut. Preliminary cuts down to 1/32 inch of final surfaced thickness can probably be made with the modified cutterhead.

New Continuous Veneer Dryer

A continuous veneer dryer incorporating the "restraint" principle of veneer drying first announced at FPL in 1950 yielded highly promising results for drying hardwood veneers under conditions that leave them markedly more dimensionally stable than when conventionally dried.

As originally worked out with a hot press, the restraint principle is based on high-temperature drying of veneer while it is restrained from shrinking by wire mesh screens. Perforated and fluted metal cauls permit vapor to escape from between the press platens. Veneer so dried has been experimentally used for flooring that is bonded directly to concrete subfloors in office buildings and slab houses.

Since press drying is a batch process, commercial utilization of the restraint principle has awaited a more economical continuous process incorporating it. Meanwhile, a need for a more effective method of continuous drying of southern pine veneer to control warp and splitting has augmented interest in the possibilities of continuous drying under some restraint.

An experimental continuous dryer was devised for trials with both hardwoods and southern pine from available equipment, principally three drying rolls and a Fourdrinier screen discarded from the FPL paper machine. The rolls were arranged triangularly, the lower ones gear driven and the upper one a "floater." Two lengths of screen were passed between these rolls, which were heated with circulating oil to any temperature desired up to about 350° F. Pressure needed to restrain veneer shrinkage was developed by tensioning the screens. Strips of veneer up to about 10 inches wide (along the grain) and 48 inches long (across the grain) were inserted between the two screens and passed through the dryer rolls at speeds up to 5 feet per minute.

In this dryer, 1/16-inch yellow-poplar and yellow birch veneer were dried to below 5 percent moisture content in 4 minutes at a speed of $1\frac{1}{2}$ feet per

M 123 259, M 123 257

Engineer Bruce Heebink examines strip of ⅛-inch southern pine veneer passed through continuous dryer between fine-mesh wire screens. Five passes through three-roll setup (equivalent to continuous pass through five banks of such rollers) produced well-dried flat veneer free of splits.

minute at a drum temperature of 300° F. Both hardwoods, moreover, were free of tension breaks and showed considerably improved dimensional stability as a result of the restraint on shrinkage imposed during drying by the screens. They were also flatter than matching veneers put through the Laboratory's commercial-type roller dryer.

Attempts to put enough pressure on ⅛-inch southern pine veneer to achieve appreciable dimensional stabilization during drying resulted in splitting. On the other hand, drying at very low screen pressure produced well dried veneer that was flat and free of checks and splits, although it shrank about as much as veneer passed through the conventional roller dryer. This was done with repeated passes through the dryer at a speed of 5 feet per minute or the equivalent of 12 minutes to attain the ovendry state. From this result it was estimated that about 8.4 minutes would be needed to dry the veneer to about 5 percent moisture content.

These findings led to the conclusion that a redesigned dryer of this type consisting of smaller rolls in sufficient number to provide continuous drying for the necessary length of time might dry southern pine veneer ⅛-inch thick more smoothly and efficiently than existing commercial roller dryers.

Experiments with this type of dryer, employing other types of rollers and perforated metal instead

of wire screen, are planned to explore the possibilities more fully with hardwoods and softwoods.

Solar Drying of Lumber

While FPL research and devlepoment work were continuing, the first commercial application of the solar dryer came into use during 1962 at the plant of a custom dryer of lumber for furniture manufacturers in Grand Rapids, Mich. Excellent results were reported in the predrying of hardwoods, as compared with air drying, before the lumber was put in a kiln for final drying.

A semicommercial solar dryer was built by the Rocky Mountain Forest and Range Experiment Station or Fort Collins, Colo., to compare drying rates and efficiency with those obtained in normal air drying of lodgepole pine and Engelmann spruce. Success of FPL experimental designs has also prompted construction of a solar dryer at the Japanese Forest Experiment Station in Tokyo, and other nations have shown interest.

Kiln Drying

Presurfaced hardwood lumber was shown to be much less prone to surface-check—develop fine cracks—than rough lumber in kiln-drying experiments with red oak 1⅛ inches thick. This finding came from a study designed to show the effects of surface roughness and board spacing on drying rates and degrade.

Neither surfacing nor wider spacing between boards appeared to affect drying rates appreciably. An experimental drying schedule somewhat severe in relative humidity—a condition that accentuates development of defects—induced checking in 32 percent of the rough-surfaced boards, while only 15 percent of those smoothly surfaced on both sides showed checks. As a commercial practice, a schedule would be used that would avoid checking but would still dry the lumber faster than the conventional schedule. Surfacing of the green lumber has further advantages because the reduced thickness of the lumber yields a still faster drying rate and increases kiln capacity, uniformity of thickness curtails warp and final surfacing, and it all adds up to cheaper drying and a better quality product.

An opportunity was afforded by a western lumber mill to study high-temperature drying in some recently completed large commercial kilns. High-temperature drying is done above the boiling point of water. Although developed in this country before 1920, it had certain disadvantages that were not overcome, and was abandoned. Since 1945, high-temperature drying has been used extensively in Europe, but only in small-scale equipment. One object of the present study was to gain information that can be used, together with other considerations, to determine the advisability and direction of further research on high-temperature drying for American requirements. Characteristics of final moisture content, degrade, and variability of kiln temperature were used to compare the performance of the high-temperature kilns with conventional kilns. If results are favorable, further research will probably be undertaken.

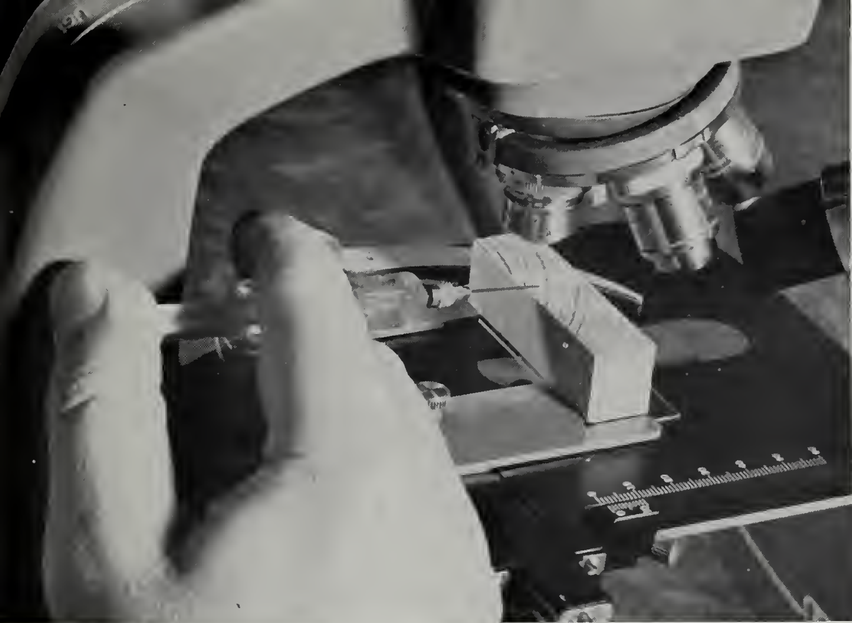
Wood Finishing

Basic research into the reasons why paints and other finishes sometimes deteriorate prematurely on wood, and to find ways of extending finish serviceability, opened several important new lines of investigation. A key study was one on physical properties of the wood surface as a substrate for finishes. It revealed the existence of high swelling strains concentrated at the interface between the summerwood and springwood of each annual ring. Measurements showed that differences in swelling between the summerwood and springwood are responsible, along with compressive stresses induced by planing. Premature peeling and cracking of paint occur over these lines of high strain.

These findings prompted the starting of studies to evaluate the effect of moisture content of wood when finished and the use of various chemical treatments to reduce swelling and protect the wood surface from biological and photochemical effects under outdoor exposure conditions. Evaluation was also begun, under outdoor conditions, of an elastomer that remains flexible on wood and therefore should, in theory at least, distribute swelling stresses more uniformly than does conventional oil-base primer paint.

Meanwhile, research was continued on the chemical and mechanical properties of films made from vinyl acetate and ethyl acrylate in various proportions. This work is preliminary in nature to the synthesis of a copolymer with properties, especially elasticity, suitable for wood surfaces. Flexibility of the films, as measured by their elongation (strain) to failure in tension, was found to depend on thickness and chemical composition. Elongation was markedly less in films with higher pigment content as well as those with the greater proportions of vinyl acetate. Ultraviolet light also lowered elongation. These findings demonstrate that much more needs to be known about the viscoelastic properties of polymers and the microcharacteristics of wood surfaces.

A study of the chemical changes brought about in wood surfaces by weathering got under way in cooperation with the National Lumber Manufacturers Association and the National Paint, Varnish and Lacquer Association. Techniques are being developed to study the photochemical effects of

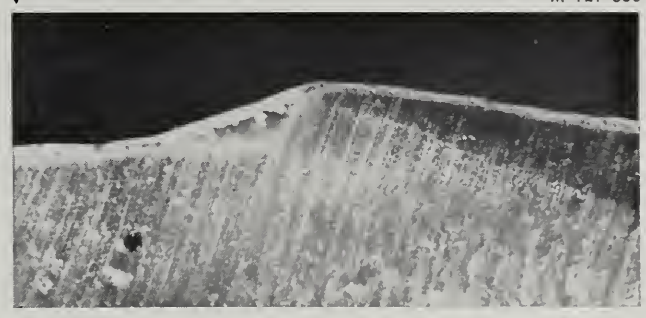


◄ M 122 862

A drop of water from this syringe entered the end grain of this painted wood specimen, causing . . .

Swelling at the springwood-summerwood interface and loosening of the paint film, as shown in this micrograph.

▼ M 121 550



exposure of wood to ultraviolet light by collection and analysis of the volatile decomposition products of these effects.

Fire Resistance of Wood

Research on the fire resistance of wood and the effects of treatments with fire retardants and other chemicals yielded substantial findings on how fire retardant chemicals affect heat decomposition of wood, the spread of flame over wood surfaces, and the rate at which wood chars.

Studies of the chemistry of the heat decomposition process, particularly as affected by fire-retardant inorganic salts, demonstrated that the effective ones, notably ammonium phosphate and borax, cause formation of more charcoal and less flammable tar than occurs in untreated wood. This is apparently due to the fact that decomposition begins at a lower temperature in the treated wood, setting up conditions that are more conducive to charring. As temperatures increase, charring continues and formation of combustibles is inhibited, so that decomposition and weight loss are greatly retarded.

The FPL 8-foot tunnel furnace was used to compare surface flammability of Douglas-fir plywood treated with decorative and fire-retardant coatings and retardant impregnants. The decorative coatings did little to reduce flammability. The better fire-retardant coatings reduced flammability by 60 to 75 percent as compared with untreated plywood, and impregnation with monoammonium phosphate reduced flammability as much as 85 percent.

The 8-foot tunnel furnace was adopted by a number of firms in 1962 for use in research evaluations and assisted one manufacturer in developing a fire-retardant, wood-fiber ceiling tile that has gained considerable market acceptance in competition with mineral tile. A number of other laboratories are also installing the tunnel, and four have begun a program for correlation of data.

The old "rule of thumb" char penetration rate for wood exposed to fire, 1½ inches per hour, is based on very limited research data. Little or nothing is known as to how species, density, moisture content, and grain orientation affect the rate.

To shed light on this important index to wood's fire resistance, especially for heavy structural members such as floor beams, arches, trusses, and roof decking, char rate studies were begun that take into consideration species density, moisture content, and related factors. Relations will also be sought between heat penetration rates, temperature gradients through the thickness of a member, and char depth properties, so that mathematical relations can be derived as aids in predicting performance of wood structures exposed to fire. The National Lumber Manufacturers Association is cooperating in this work.

Microclimate Effects

The significance of environment with respect to the serviceability of wood products under outdoor exposure received nationwide study during 1962 at weather exposure sites established the year before near Olympia, Wash., Fresno, Calif., and Gulport, Miss. Each site was stocked with closely comparable specimens of lumber, laminated wood, plywood, and particle board, as well as paints, natural finishes, preservatives, and wood glues of various types. These exposure sites, together with the one long maintained at Madison, Wis., are coordinated so that reliable evaluation can be made of the effects of the four types of climate representative of the principal areas of the United States.

Progress was also made in the development of special instrumentation needed to measure and record microclimate conditions at the four exposure sites—that is, actual temperatures, humidity, and associated conditions prevailing on the surfaces of and within exposed specimens. A University of Wis-

consin meteorologist is cooperating in this instrumentation work. A technique for measuring the temperature of a surface coating was perfected in trials of microthermocouples and recording apparatus at the Madison site.

This work will be extended at Madison during 1963 with a basic study of instrumentation and wood-climate interaction. Results will guide future microclimate studies at the other exposure sites. Temperature and moisture content of wood through day-night and seasonal cycles will be charted to learn how these factors are affected by solar radiation, air temperature, relative humidity, and wind velocity.

Decay Prevention Treatments

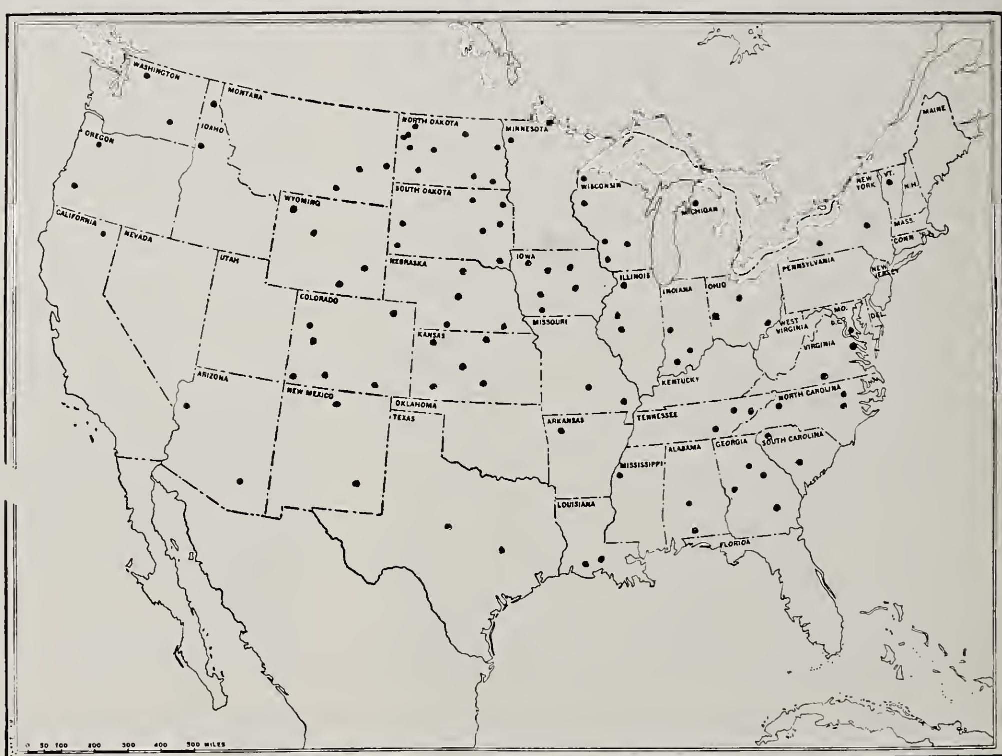
One of the longest—if not the longest—service records emphasizing the value of preservative treatment for wood under severe decay-hazard conditions was concluded in 1962—exactly 51 years after it had begun. In 1911, the Milwaukee Railroad entered into a cooperative agreement with FPL to install and keep service records on creosoted railroad ties of several species in a section of track just south of Madison. The final results demonstrated that well treated ties can have an average life of more than 50 years compared with a 12-year average for untreated white oak and 9 years for untreated red oak under Wisconsin conditions.

Since 1949, a nationwide study of the service life of preservative-treated utility poles has been under way in cooperation with the Rural Electrification Administration and nearly 100 rural cooperatives financed through REA. A 1962 progress report showed that 6,562 poles of nine species treated with different preservatives are under surveillance, with inspection by FPL specialists at approximately 5-year intervals. Results emphasize the need, stressed in the progress report, for quality control and adequate penetration of preservative in treated poles. Failure can be expected as soon as 4 to 13 years after installation if these requirements are not met, the report points out.

Southern pine poles can be protected from fungus infection in Louisiana while being air seasoned before preservative treatment if soaked for 15 to 60 minutes in a 30 percent ammonium bifluoride solution, results of a pilot plant experiment showed.

A study of the effectiveness of so-called "groundline" treatments of utility poles already in place is under way in the Harrison Experimental Forest of the Forest Service near Gulfport, Miss. Such treatments are commercially offered to utilities, but their effectiveness has been open to question. In this study, sections removed from western redcedar poles 4 years after treatment showed that preservative was not uniformly distributed, even in easily penetrated sapwood, and did not enter heartwood. The study is continuing.

Experiments with species that are hard to treat with preservative even under pressure are under way to improve treatment. Redwood heartwood lumber was treated at different moisture content



M 121 455

Utility pole installations owned by REA cooperatives and under periodic observation by FPL preservative specialists are located at points shown.

levels to learn how this factor would influence penetration and absorption of chemical. Other species to be included are Rocky Mountain Douglas-fir and Engelmann spruce and Alaska-grown Sitka spruce, white spruce, and western hemlock.

A new method of assaying creosote-treated wood is under study for possible use by buyers of piling, poles, and other treated products. It is based on color comparisons of solutions containing known amounts of creosote with solutions obtained by extracting samples of treated products. The method makes possible the assaying of individual treated items.

The double-diffusion method of treating wood developed at FPL continues to win adherents. Most recent is the Virginia Highway Department, which specifies the method as acceptable for highway posts. Commercial plants known to be using the process include three in Florida and one each in South Carolina and Virginia.

The process has been especially successful in giving protection against fungi in giant water-cooling towers built of wood by petroleum refiners and other concerns that use water to cool processing equipment. Flowing water leaches natural decay-preventing extractives from the wood, which then must be treated against rot. Double diffusion, by putting chemicals in the wood that react to become insoluble, has proved especially suitable for protecting such structures in place.

Nontoxic Treatments

Treatments that render wood immune to fungus attack either by chemically modifying it or by removing thiamine necessary for fungus growth showed sustained advantages during exposure to high-hazard decay conditions.

Wood treated by cyanoethylation, which renders cellulose unassimilable by fungi, was found to possess altered surface properties, notably improved dimensional stability. Wood samples sprayed with the chemical were therefore coated with a clear finish and exposed outdoors and to accelerated degrading conditions in the laboratory to determine whether the improved surface stability of the wood contributes to finish durability as well as providing decay protection.

Thiamine-depleted wood panels exposed on the Harrison Experimental Forest in Mississippi several years ago continued to show good resistance to decay in comparison with untreated wood that has become badly decayed. Treated panels painted to prevent subsequent uptake of thiamine by the treated wood from airborne contaminants were exposed to ascertain whether the paint helps.

Preventing Decay in Buildings

Two series of investigations are showing promising results for simple treatments of wood on building exteriors, notably porches, steps, and railings. A 7-year experiment in cooperation with the Southern and Pacific Northwest Forest and Range Experiment Stations showed that precut lumber of a variety of species can be well protected from decay in a variety of climates when used out of contact with the ground if given a simple 3-minute dip in a 5-percent pentachlorophenol solution.

Treatment of wood in place was carried through laboratory experiments with considerable promise in a study conducted in cooperation with the Navy. Pentachlorophenol in oil and grease form was used to protect typical wood joints where moisture can collect and set up decay hazards in outdoor wood construction. Final appraisal of these treatments awaits results of long-term outdoor exposures, especially as regards the ultimate value of certain treatments shown to be marginal in laboratory experiments.

Natural Decay Resistance

Great differences in natural decay resistance have long been known to exist among species. The superiority of such species as redwood, cedar, white oak, and baldcypress has been attributed to the presence of fungitoxic extractives in the heartwood. A series of experiments has been under way for several years on the decay-inhibiting effectiveness of extractives removed from such woods. This work is being done in cooperation with the University of California Forest Products Laboratory. A few of the extractives obtained have shown considerable effectiveness. The work is being continued with other compounds in efforts to establish relationships between fungus toxicity and chemical structure, with the ultimate goal of deriving or compounding superior preservatives.

In another series of studies, small samples of redwood taken from trees throughout the growing range of this species were evaluated for decay resistance. While substantial, it was not so high as redwood commonly is believed to possess. Field studies will be made to learn whether redwood posts and other large members have better decay resistance because extractives migrate from the interior of the piece to reinforce fungus resistance at the surface.

Conventional kiln drying was shown to reduce decay resistance of redwood only slightly.

Soft-Rot Fungi

The discovery of so-called "soft rotters" some years ago and subsequent studies of their life cycle

and related characteristics led to the attainment of a long-sought goal—development of techniques permitting reliable culturing of these organisms. This is a long step toward better identification procedures and attainment of more effective preservatives. Evidence has been found, for example, that these fungi can modify and render ineffective such common wood preservatives as the toxic arsenic compounds, which they apparently change into harmless volatiles.

Subterranean Termites

A previously discovered termite attractant derived from decayed wood has shown promise of bringing termites at least intermittently to lethal baits in experiments at two known Wisconsin colonies of these wood-attacking insects. At those locations, termites appeared to forage through the top 2 or 3 inches of soil, and attractant chemicals were dispersed near the surface to determine their possible effectiveness with baits. Light, temperature, and relative humidity apparently influence the degree of termite response to the attractant.

Experiments with concrete treated with a commercial insecticide showed that, after 2 years of indoor or outdoor exposure, the concrete still proved lethal to termites that attempted to crawl over it, killing them on contact. It is estimated that treatment of the foundation of an average home would cost about $25. The experiments are to continue for 5 years to evaluate long-term efficacy of the treatment.

Powderpost Beetles

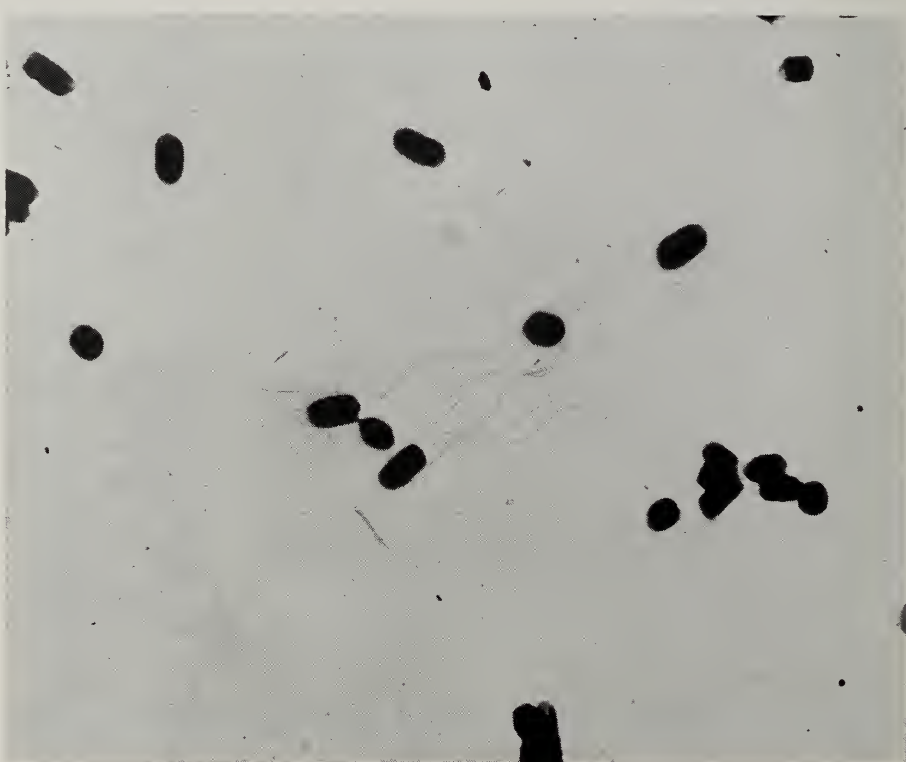
A search for an insecticide that, when applied to freshly cut lumber, remains effective against powderpost beetles through kiln drying, has been successful at least to the extent that eggs deposited by the insects do not hatch out. The object of this work is to protect lumber and paneling from infestation at the building site.

Hardwood Discolorations

Discolorations that develop in sapwood of certain hardwoods during air seasoning were traced in part to chemical changes in the starch content of wood rays. To what extent environmental factors govern development of the discoloration is being studied as a means of avoiding it through improved handling and seasoning practices.

Bacterial Action on Wood

Clear evidence that bacteria grow in wood much as fungi do has been obtained in studies of several species. Weight losses as high as 7 percent have been found in bacterially infected wood, but there has been no detectable loss in strength such as accompanies weight losses caused by fungi.



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Electron micrograph of bacteria extracted from wood. Long, threadlike projections are flagella used for movement. Magnification 10,000X.

M 123 368

Glass tube containing termite attractant is used to study migration habits of these insects. Indications are they remained at or near surface of ground even in prolonged dry weather.

M 121 825

Termites exterminated while moving across concrete treated with a common insecticide when poured 2 years before.

Bacterial action consists of enzymatic degradation of certain components of wood, by which a carbon and energy supply needed for bacterial growth is obtained. Bacteria identified in wood include *Bacillus subtilis, B. polymyxa,* and *Aerobacter celoacae.*

Special interest in bacterial decomposition of wood is centered upon the increased permeability caused by these organisms. Experiments are planned to determine whether this permeability will facilitate the treatment of wood with decay-preventative and fire-retardant chemicals.

WOOD FIBER PRODUCTS RESEARCH

FPL research on wood fiber products during 1962 continued to place major stress on pulping and papermaking processes and problems. In both variety and productivity, process developments were designed to meet demands for greater efficiency and economy in recognition of competitive conditions and raw material requirements of the industry. With consumer needs steadily increasing and pulp and paper constantly being adapted to new uses, producer interest in more complete and effective use of available fiber in wood heightened accordingly.

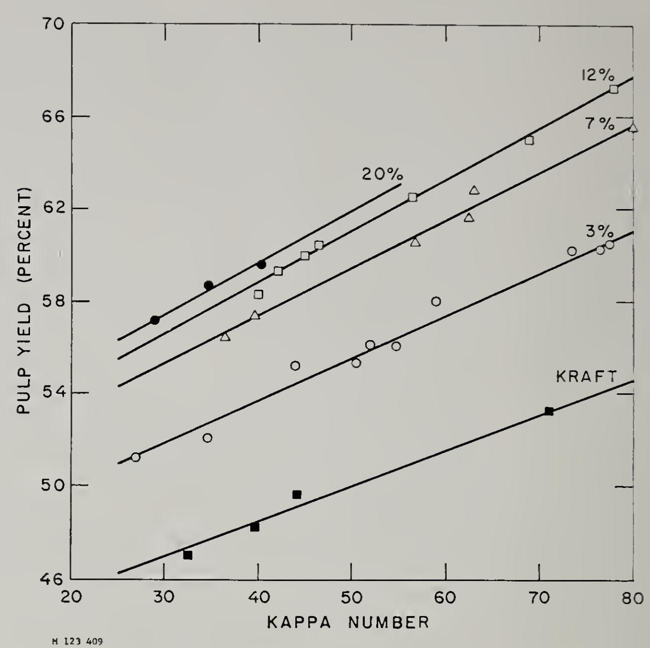
Both fundamental and applied research are trained upon the problems of producers and consumers that inevitably accompany these needs. Pulping processes geared to more complete conversion of wood to usable fiber, basic studies of fiber structure and bonding, and improvement of paper and container board sheet properties comprised prominent elements of the FPL research program directed to these ends.

Development of new and improved pulping processes aimed at higher fiber yield and quality was pursued through studies largely concerned with the chemical reaction and physical behavior of cell-wall components during pulping. Under specific investigation were chemical pulping processes with compounds of sodium and sulfur, and of prime interest in this work was the mechanism of the chemical reactions involved. This research is predicated upon the premise that results of fundamental importance will have general applicability throughout the industry and for a wide range of species.

Chemical Pulping

The two basic chemical pulping processes long in use for producing paper from wood for a great variety of uses, from containers, bag, and wrapping papers to fine printing and writing sheets, remain the sulfite and the sulfate, or kraft, process. Both, of course, have undergone great modifications as the need for adaptation to new species or production of new products has arisen. With the object of getting higher yield, FPL research has been concentrated on three variants, polysulfide, bisulfite, and alkaline sulfite pulping.

As first reported last year, polysulfide pulping is under study to increase the efficiency of the basic kraft (sulfate) process for southern pine. Polysul-



M 123 409

How polysulfide improves yield of loblolly pine pulp when added to kraft liquor. Bottom line is a typical kraft pulp, other lines show effects of adding polysulfide sulfur in amounts from 3 to 20 percent of the weight of the wood.

fide is in effect a sulfur-rich form of sodium sulfide containing one to four or more atoms of sulfur per molecule. Sulfur is a key ingredient of the pulping liquor for solubilizing lignin quickly and with relatively mild action to reduce loss of cellulose and hemicellulose.

Yield of kraft pulp was increased 20 percent or more when 20 percent of polysulfide sulfur (based on the weight of the wood) was added to the cooking liquor. This represented a substantial improvement in yield over results previously reported.

Progress was also made in raising the yield at a given polysulfide level and otherwise improving the efficiency of polysulfide. It was found, for example, that the decomposition rate of polysulfide in alkali is very markedly increased at higher temperatures—indicating that lower cooking temperatures should serve to raise its effectiveness. Digestions at 140° C., for example, raised yields 2 to 3 percent at a given polysulfide level as compared to digestions at the more common 160° to 170° C., thereby contributing to better efficiency. Work is continuing to obtain data needed to determine the technical limitations as well as the possibilities of recovering the chemical for reuse. Practicality of the process is, of course, contingent upon development of an efficient recovery system, which remains to be done.

Related studies of the chemical reactions involved in polysulfide pulping disclosed, among

other things, that the selectivity of delignification is due not to increased rate of lignin dissolution but to protection and retention of the hemicelluloses. The yield is increased mainly because of greater retention of glucomannan, accompanied by small improvement in yield of xylan and cellulose. Work is progressing on the reaction of wood polysaccharides with polysulfides.

So-called multistage sulfite pulping, involving two-stage cooks with neutral and acid sodium sulfite liquors, has been found to produce either more but slightly weaker pulp than single-stage acid sulfite pulping or equal amounts of stronger pulp, depending upon whether the neutral or acid stage comes first. During the past year, this process was tried on Douglas-fir, which is difficult to pulp by the conventional sulfite process. By appropriate control of the pH (a measure of acidity or alkalinity) in each stage, considerable increases in strength or yield were obtained. Strength comparable to that of kraft pulp, however, was obtained only by a more drastic treatment in the alkaline sulfite second stage than is needed with other wood species that have been tried.

Two-stage pulping of Douglas-fir was tried with magnesia-base sulfite liquor for the first stage, followed by a cook with liquor made alkaline by adding ammonia. Magnesium sulfite is attractive for pulping because it is readily recoverable. The ammonia was used because magnesium sulfite, which is readily recovered, is, unlike sodium sulfite, not soluble in alkaline media, but precipitates out at a pH in the neighborhood of 6, still on the acid side.

For a terminal pH of 9, the magnesium-ammonium process gave pulps about 10 percent weaker in bursting strength and only slightly weaker in tearing resistance than those obtained with two-stage sodium sulfite pulping. For a given bleach requirement, however, the process did give 4 to 5 percent more pulp. It is believed that this results from a lower concentration of hydroxyl ion at the digestion temperature than the liquor pH measured at room temperature indicated.

Alkaline sulfite pulping liquors were also tried in single-stage pulping on Douglas-fir. Past experience had shown that this process produces pulps of excellent quality but low in yield, and that much

Dr. Herbert Schroeder adjusts a flash evaporator used to concentrate hemicellulose solution for experiments in polysulfide pulping.

M 123 485

Technician Erwin Elert lowers a metal "bomb" containing wood and pulping liquor into hot oil bath for small-scale pulping experiment.

M 123 484

chemical and long cooking times are needed. By cooking the Douglas-fir chips to higher yields of pulp and by adjusting the nature and amount of the reagent used to control alkalinity, important reductions in chemical and time needed were achieved. Yield rose from 45 to nearly 60 percent without serious loss of bursting or tensile strength, although tearing strength dropped moderately as yield rose above 50 percent. Delignification rate was greater when sodium sulfide was used instead of sodium hydroxide as the alkali buffer.

Yield of spruce pulp was raised about 10 to 15 percent by adding small amounts of sodium borohydride to the alkaline cooking liquor. The gain was attributed largely to increased retention of glucomannan; strength loss was only moderate. Yield reached a maximum at an optimum level of alkalinity of the sulfite liquor. Experiments will be continued with Douglas-fir to establish the smallest amount of borohydride needed and the most efficient means of applying it, since borohydride is a relatively expensive chemical. Studies of its effect on delignification rates and its interaction with sodium sulfide in this process will be made to obtain data on yield useful in determining the mechanism of alkaline pulping reactions in general.

Pulps obtained from coniferous woods by alkaline sulfite pulping will be evaluated for their suitability in linerboard, bag, and other brown paper uses.

Experiments showed that, among various alkaline liquors, a combination of sodium sulfite and sodium sulfide was most selective in removing residual lignin from high-yield spruce bisulfite pulps. In these treatments, borohydride effectively retarded degradation of carbohydrate. The objects of this work are to raise tearing resistance of softwood sulfite pulps to that of kraft pulps, to improve pulp strength, and to reduce bleaching chemical requirements

The practical utility of many of the newer pulping processes, as well as that of kraft and semichemical pulping, hinges on recovery of sodium and sulfur. The reactions of sulfur compounds during pulping and recovery of cooking chemicals are complex and poorly understood. Studies are under way to develop reliable procedures for analyzing the various mixtures of sulfur compounds and establish the equilibria involved in pulping and recovery reactions. Information obtained may prove valuable in developing better pulping or chemical recovery methods.

Fiber Structure and Bonding

The complex chemical and physical structure of pulp fibers bears strongly on their papermaking qualities. Regardless of species, any pulping process produces fibers with widely varying chemical and physical characteristics. Better understanding of the significance of these variations is essential to put pulp and paper manufacture on a firmer scientific and engineering foundation.

Research is under way at FPL on the relationship of fiber structure and composition to several phases of pulping and papermaking. Among techniques used to study fibers are solvent and mechanical separation of the cell-wall layers, effects of beating on fibers produced by the different chemical processes, and formation of bonds between fibers produced in various ways.

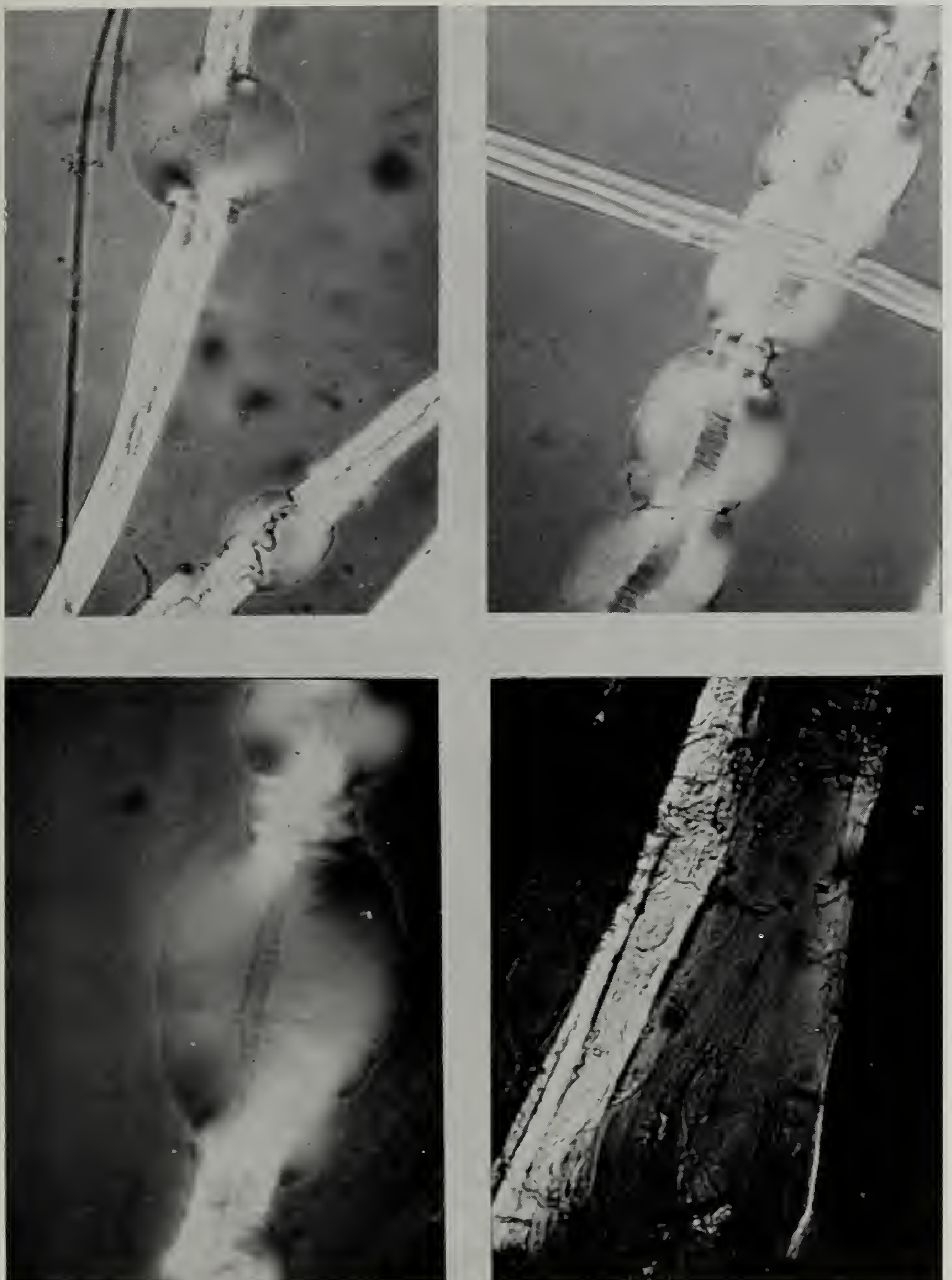
Microscopic study of fibers is yielding significant information about the effects of a given process on the fibers—information of considerable potential significance to the solution of pulping and papermaking problems. Study of Douglas-fir kraft pulp fibers has yielded clear evidence, for example, of the effects of pulp chemicals on the sleevelike fiber walls. Generally, the chemicals removed the lignin around the fibers and in the outer portions of the fiber wall to expose the cellulose-rich inner portions, which are responsible for fiber-to-fiber bonding in the paper sheet.

The effects of such mechanical processing as beating, which is done to improve the fiber-to-fiber bonding of chemical pulps when converted to paper, are also being studied. Microscopical examination of the beaten pulps aids in the practical evaluation of processing equipment and in subsequent correlations with paper properties.

Microscopic studies of ponderosa pine kraft fibers beaten to a certain freeness (water drainage rate on the paper machine) showed, for example, that the fiber wall had been split open longitudinally during beating; in some cases the outer fiber wall had been completely removed in sleevelike fashion. Splitting had the effect of greatly increasing the external surface of the fiber and thereby the potential bonding area, which helps explain why beating improves paper strength.

Other fiber studies with the microscope have shown the differing effects on fibers of different pulping processes. A jack pine sulfite pulp produced by two-stage sulfite (neutral followed by acid) pulping underwent extensive fibrillation of the inner (S-2) layer of the secondary fiber wall when beaten. A jack pine kraft pulp underwent much less fibrillation of the S-2 layer, remaining more intact and therefore stronger.

Fiber-to-fiber bonding is generally thought to result from hydrogen bonds akin to those that cross-link cellulose molecules to one another. In the formation of paper, drying of fibers causes them to shrink and draw closely enough together to permit formation of such bonds between fibers in which the cellulose-rich inner walls have been adequately exposed.



M 122 693

Structural variations in chemically swollen kraft pulp fibers of different species, as revealed under the microscope. Upper left, Douglas-fir fiber magnified 175 times; upper right, southern pine fiber magnified 85 times; lower left, sweetgum fiber magnified 175 times; lower right, beaten ponderosa pine fiber magnified 920 times.

Other types of bonds between fibers also have been observed under the microscope. Some are formed by fibrils that extend from one fiber wall to an adjacent one; such bonds have been noted in beaten sweetgum kraft pulp. Filmlike lamellar bonds between sweetgum fibers have also been observed to be present where fibrillation of the inner wall did not take place during beating. Study of the dynamic behavior of these types of bonds during drying of extremely thin sheets of paper is planned, using motion picture techniques, as part of research on their relative quality.

A new microscopical technique called vertical polarized illumination shows promise of yielding new information about fiber bonding by facilitating study of the areas where fibers cross and bonds are thought to form. Mixtures of dyed and undyed fibers are used to improve visibility of the bonded areas.

Improving Paper Stiffness, Stability

A discovery reported last year, to the effect that restraint during drying results in a stiffer and more dimensionally stable sheet of paper, was further

investigated. Improved sheet stiffness holds prospects for stiffer structural types of paperboards, while better dimensional stability is important in map papers, color printing papers where color register is critical, and sorting-machine and computer punch cards. Results of the continuing experiments have thrown considerable light on causes of differences in tearing strength, stiffness, and dimensional stability of papers as between the machine and cross-machine directions of the sheet.

Curved expander rolls on the paper machine have been found to widen the sheet as it is formed, thus counteracting shrinkage. Sheet stiffness in the cross-machine direction was increased about 30 percent with two expander rolls contacting the sheet when its moisture content was about 50 percent. A similar gain in dimensional stability was achieved when two expander rolls were placed in the wet press section.

Results of the experiments have excited wide interest in the industry.

Wet-Strengthened Container Board

Treatment of corrugated container board with phenolic resin was found to be the most effective and promising of a number of such treatments tried in research on means of improving wet strength. The work is continuing, in cooperation with the Air Force, to develop containers for military uses in tropical climates, where high humidity for long periods seriously weakens them during storage. Damage to contents is a frequent result. The work has direct application also for poultry processors, fruit and vegetable growers, and others in need of containers that can withstand widely fluctuating conditions, as when packages are transferred from refrigerating to normal temperatures.

Treatment of only the liners in corrugated board was found in one study to give the board adequate strength at high humidities even with the use of an untreated corrugated sheet. Addition of 8 percent of phenolic resin to linerboard surfaces increased compressive strength at 90 percent relative humidity substantially as compared with untreated board. Loss of strength was only about 20 percent as compared to a 50 percent loss in untreated linerboard. A similar improvement was obtained by adding 9½ percent of starch cross-linked with 2½ percent of phenolic resin. Equal improvement without chemicals would require increasing the weight of the board by adding proportionately more fiber. Resin treatment would increase board cost 32 percent, starch-resin treatment 20 percent, and addition of fiber 65 percent.

The distribution of chemicals within the boards is being studied microscopically to find explanations for differences between treated boards or papers with respect to strength and other qualities. For example, a dry board to which starch-phenol resin was added at the size press was considerably stronger than one that was wet when the chemical was added to it at the smoothing press. In the stronger board, microscopic examination revealed, the resin had penetrated only slightly below the surface, while the wet board was uniformly penetrated throughout its thickness. Fluorescent and ultraviolet microscopy are being employed to identify chemicals unresponsive to staining.

WOOD CHEMISTRY RESEARCH

In FPL's broad program of research, chemistry finds a place in extending our knowledge of the nature and behavior of wood, improving its utility in natural or modified forms, and extending its usefulness as a source of industrial chemicals. Certain familiar industries, the most prominent of which is pulp and paper, depend largely on chemical transformations of wood to yield diverse products of the desired properties. A segment of the vigorous chemical industry, now based so heavily on petroleum, is expected to draw increasingly on products of the forest. But nearly all aspects of forest products utilization can benefit markedly from extended knowledge of the chemical and physical-chemical nature and behavior of wood.

M 123 605

Dr. Milton Feather discusses with colleagues possible reaction mechanisms in chemical conversion of hemicelluloses.

Carbohydrate Research

Hemicelluloses differ from the cellulose portion of wood carbohydrates in that they have much shorter molecules of more complex chemical structure. Chemical behavior, therefore, differs considerably. The common method of isolating hemicelluloses from the total carbohydrate fraction of wood by treatment with a 17.5 percent solution of sodium hydroxide is known to result in compounds that are considerably altered from the original hemicelluloses. One goal of basic FPL carbohydrate research, therefore, is to find ways of separating hemicellulose undamaged from the holocellulose complex in wood, so that the chemical structure can be precisely diagrammed and standard reference preparations made available. Another purpose is to learn the physical distribution of hemicelluloses in the fiber structure of wood. The work has application also in pulp and paper manufacture, since hemicelluloses may be of considerable aid in forming fiber bonds in the sheet. And it contributes to the understanding of wood properties as influenced by chemical composition.

Exploratory work toward this goal is under way on aspen wood. A mild treatment with dimethylsulfoxide is being used to isolate the hemicelluloses from this species, and xylan and acetylxylan of high purity have been obtained. These, together with their hydrolysis products, are being analyzed by means of new thin-layer and column chromatographic techniques to elucidate their chemical and physical structure.

Related research on hemicellulose chemistry is being carried on to clarify the chemical mechanism by which xylose sugar (a component of hemicellulose) is converted to furfural. Recent work has shown that the reaction does not proceed directly to furfural but that intermediate products are first formed. Identification and study of such intermediate products is the immediate object of this work. The long-term goal is to find useful products and perhaps new processes for xylose utilization.

Wood Conversion Reactions

In the development of processes for the chemical conversion of wood, the chemical engineer today prefers to optimize his process and plant design on the basis of measured values for the rates and extents of the many reactions involved. FPL has put much effort into the development of equipment, techniques, and analytical methods which permit the gathering of such information on a highly efficient basis.

In one such piece of work, the delignification of aspen with sodium xylene sulfonate was studied. This system was chosen because it served as a good model system in technique development. It also has some features which make it interesting as a means of separating lignin from cellulose, a possible first step in utilizing great quantities of wood residue.

It was found that excellent delignification could

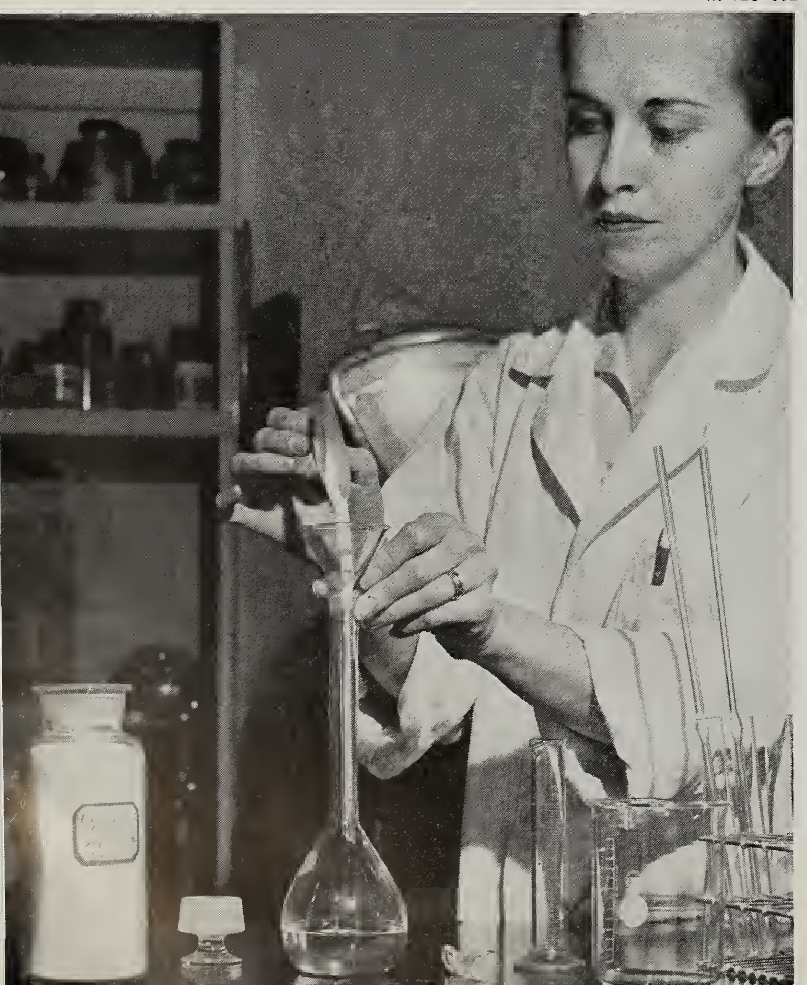
be achieved with sodium xylene sulfonate without excessive damage to the cellulose. It was shown for the first time, too, that the reaction is greatly accelerated by increased acidity and that high acidities do not cause excessive damage to the cellulose. This is because the lignin-removing reaction is accelerated more than the cellulose-degrading reaction.

Many of the wood reactions of interest in chemical utilization are acid-catalyzed reactions, and for a number of reasons conventional measures of acidity fail badly in predicting catalytic activities. In the case of the hydrotropic delignifying agent, sodium xylene sulfonate, the conventional measure of acidity is quite useless. Further, the important thing to know is the acidity at the high temperatures used for carrying out these reactions. A program of research was undertaken to clarify this problem.

To interpret the delignifying data obtained in the previously mentioned study using sodium xylene sulfonate, a companion study on the rate of degradation of xylose was carried out. That is, data were collected over the same range of conditions in the same medium, replacing wood with xylose. The acidity of the system was thus measured in terms of the rate of degradation of xylose. The same measure of acidity may be used with other systems and will allow one to compare the effectiveness of various lignin solvents. This measure of acidity is also useful for predicting the rate of destruction of other sugars in other acidic mediums when only a minor amount of experimental data is available.

Bacteriologist Barbara Spring prepares for analysis a solution of erythritol, white sugar-like powder obtained by fermentation of wood sugar with osmophyllic yeast.

M 123 602



Biochemical Conversion Products

A continuing program of fermentation research seeks to make use of the sugars appearing as byproducts in pulp or coarse fiber production, or sugar which might be produced as a primary conversion product from wood waste.

A recent study completed in cooperation with the University of Wisconsin, and with partial support of the National Science Foundation, has established the conditions under which a yeastlike fungus can be made to produce erythritol in yields of 35 to 40 percent. Proper control of phosphate level, nitrogen level, and aeration results in high yields and keeps production of coproducts to a minimum. This fermentation process is capable of taking erythritol out of the rare chemical class, selling for very many dollars per pound, and making it a tonnage chemical selling at a price common for such materials.

With the completion of this work, erythritol joins two other polyols, glycerol and arabitol, which studies have shown to be economically producible by fermentation processes.

Lignin Structure, Utilization

Research continues to chip away at the mysterious lignin molecule, gradually establishing new knowledge of its real structure in wood. Solution of this mystery would have beneficial effects in a wide range of chemical and fiber uses of wood by shedding new light on the nature of chemical processes used to convert wood to many things.

Model compound studies, so-called because they start with compounds that contain portions of hypothetical lignin structures, have brought out indications that lignin may contain polyphenyl linkages and nonaromatic ring structures in addition to the biphenyl group earlier discerned. These are all building blocks of molecular structure that are so complex that no known method is capable of removing lignin without damage.

Chemical experiments designed to remove lignin with minimum change are of course continuing. One promising new method is treatment of wood with aqueous dioxane-hydrochloric acid and simultaneous hydrogenolysis, which removes lignin by a process of hydrolytic degradation. Byproducts from the carbohydrate portion are also obtained, however, and present a problem.

Analytical techniques have been improved by experiments in the oxidation of lignin with nitrobenzene and studies of the cleavage products so obtained. A previously unidentified oxidation product is under investigation.

Chemicals From Bark

The bark of a few tree species has been used as a source of chemicals for a long time. Leather tanning agents are still obtained from hemlock and some other species, and cork is a well known bark product. Redwood bark fiber is used in insulation. On the whole, however, bark is generally discarded or, at best, used for fuel at mills where it accumulates.

One reason for such limited use of a raw material that is widely available is that the chemistry of bark is little known. Research on fundamental bark chemistry has in recent years been accelerated at FPL to provide the essential information that is obviously needed as a foundation for broad utilization. Work has, so far, been done mainly on barks of the softwoods, jack pine, loblolly pine, lodgepole pine, Pacific silver fir, sugar pine, and western white pine.

The benzene extract of jack pine bark has been shown to contain abietic and dehydroabietic acids and pinusenediol, a new triterpene, among other compounds. Pinusenediol has also been extracted with benzene from sugar pine and loblolly pine bark. A major component of the benzene extract lodgepole pine bark, which is unusually soluble in this solvent, has been found to be manool, a nonvolatile, oily diterpene alcohol. Among a number of sterol fractions obtained from jack pine benzene extract, the main one was β-sitosterol. Gas chromatography has been developed as an aid in identification of these extractives.

Pine Wood Extractives

The naval stores industry is one of long standing in United States and world economy. Its annual output involves 1 billion pounds of resin and 30 million gallons of turpentine, together with 14 million gallons of pine oil, pine tar, and other miscellaneous products, all produced from the extractives or exudates from longleaf and slash pine in the southern United States. With expected depletion of stump-wood supplies over the next few decades, production of naval stores will lean more and more heavily on gum and tall oil supplies, the latter being a byproduct from the kraft pulping of southern pines.

In anticipation of such changes in the supply base for naval stores, a long-range cooperative arrangement between the Forest Products Laboratory and the Pulp Chemicals Association has been set up to carry out fundamental studies on the basic nature and composition of pine wood extractives, their role in the physiology of the tree, and the changes induced during commercial pulping operations.

Initial efforts are being devoted almost exclusively to the development of analytical techniques for the separation, identification, and quantitative determination of the various extractives of five representative southern pine woods. Chromatographic procedures (gas, paper, and thin layer) are being given the prime role in this developmental phase of the work. Among the components under investi-

Chemist David Johnson operates spectrophotometer recording ultraviolet spectrum of lignin solution over wave-length range of 400 to 240 millimicrons.

M 123 599

Optical properties of a resin acid extracted from pine wood are checked in polarimeter by Dr. Duane Zinkel.

M 123 594

gation are mixtures of resin and fatty acids and their esters.

Physical Chemistry

Studies of the physical chemistry of wood deal principally with two surface chemistry factors, adsorption of polymers and surface stabilization. The polymer adsorption study has as one object the gathering of data on factors that contribute to or detract from surface adsorption. The stabilization study, begun during 1962 in cooperation with the National Lumber Manufacturers Association and the National Paint and Varnish Manufacturers Association, is designed to produce basic information on the requirements for surface stabilization against swelling and shrinking, with the object of improving finish-holding properties for coatings such as paints and varnishes.

Surface adsorption experiments with polyvinyl acetate showed that there is a marked difference in adsorptive capacity between the two main components comprising the total external surface of wood. The portion comprised of exposed lumen walls (49 to 90 percent of the total, depending on species) is much less adsorptive than the portion consisting of cut and exposed wood substance within the cell walls. Certain swelling pretreatments accentuate these differences in adsorptive capacity to more than tenfold. From these findings it was concluded that the chemical composition of the immediate surface of the lumen walls differs considerably from the usual carbohydrate-lignin complex of wood substance.

Exploratory experiments on surface stabilization yielded evidence that surface swelling and shrinking can be substantially reduced in this manner. Diffusion characteristics of different stabilizing chemicals into the side grain of wood are being systematically studied to lay a groundwork for this research by uncovering factors that influence the development of shrinkage stresses near the surface during drying.

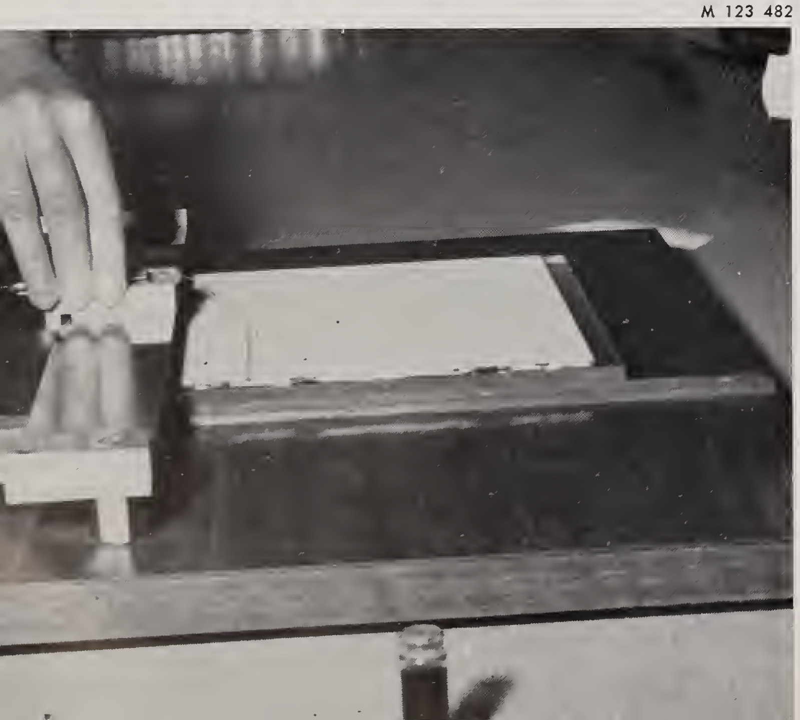
Analytical Development

The availability of precise analytical techniques is a major key to progress in any field of research. It is of special significance in wood chemistry, where the great diversity of chemical constituents both contained in and desirable from wood and wood residues creates the need for equal diversity of measuring techniques. Recognizing this need, FPL has a continuing program of activity in the development, adaptation, and modification of analytical procedures. Many of these ultimately attain the status of standard methods accepted by the entire wood-using industry.

Of current interest are the extremely sensitive separation techniques of paper, gas, and thin-layer chromatography. While now in common use, these techniques are undergoing considerable modification to adapt them to the special problems encountered in wood chemical analysis. Thin-layer chromatography, for example, is easily qualitative in its present state of development. Research now under way is aimed at developing rapid routine procedures for making quantitative each step from the application of an unknown mixture of components to the plate to the final measurement of the amount of each separated component. Possibilities for combining thin-layer with gas chromatography, whereby full advantage can be taken of the best features of each, are also under investigation.

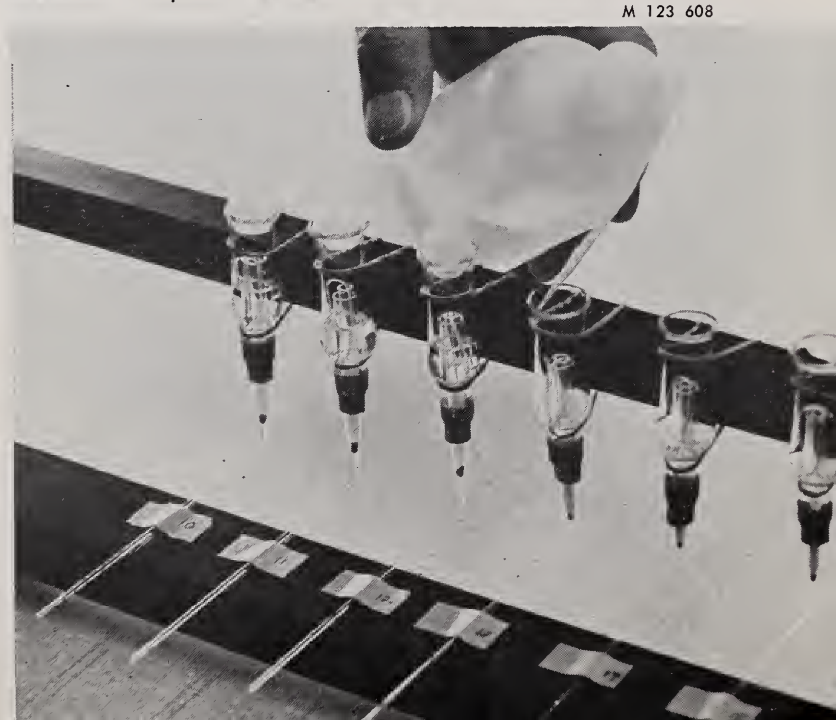
Applying solution of unknown compounds to coated glass plate for analysis by thin-layer chromatography.

M 123 482



Elution apparatus used to separate compounds from coating materials used in thin-layer chromatography. Separated compounds are subsequently identified by chemical or optical means.

M 123 608



INFORMATION ACTIVITIES

Putting the results of FPL research to use is itself a big job—a job of communications, of getting information to people in need of it. Practically everyone uses wood and its products, and hundreds of thousands earn a livelihood by harvesting, manufacturing, distributing, and selling them. The number of persons who can validly be assumed to need FPL information is, therefore, large indeed.

The official publications issued by FPL represent one major channel of communication with the wood-using public. These publications range from the highly technical, designed for a limited readership in need of complete data on research findings, to broad segments of the population requiring only the essence of research telling how to apply and use the results.

During 1962, FPL prepared a total of 103 publications. These included 53 technical and trade journal articles, 44 processed reports printed and distributed directly, a U. S. Department of Agriculture Technical Bulletin, 3 processed technical notes, a USDA Agriculture Information Bulletin, and a document published by the Committee on Public Works of the United States Senate. In addition, the Department of the Army published, under date of July 11, 1962, the third edition of Military Handbook 7A, "Lumber and Allied Products," as revised by FPL. This document was prepared by FPL for the Army Corps of Engineers and first published in 1953, primarily to guide Army, Navy, and Air Force procurement of wood products ranging from lumber and plywood to poles, piling, railroad ties, and similar items.

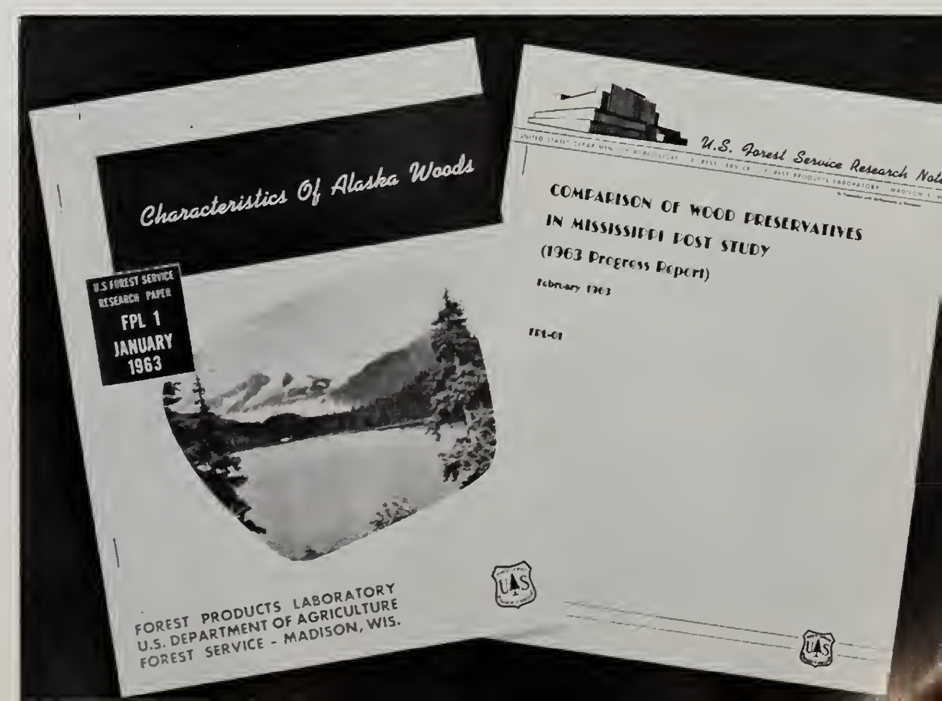
A complete list of FPL publications during 1962 is appended to this report.

The USDA Technical Bulletin is entitled "Machining and Related Characteristics of United States Hardwoods." It presents the results of many machining experiments with modern power woodworking equipment on the major hardwood species grown in all parts of the Nation, with recommendations for cutter speeds, rates of feed, and other operating fundamentals. Copies can be purchased from the Superintendent of Documents, Government Printing office, Washington 25, D. C.

The USDA Agriculture Information Bulletin issued is entitled "The Forest Products Laboratory, a Brief Account of Its Work and Aims," and tells about its organization and program of research in layman's language.

The 44 processed reports and 3 technical notes printed and distributed directly by the Laboratory cover the newest deevlopments in research during 1962 along many lines. Single copies of these may be obtained free by writing to the Director. Up-to-date lists of publications on various fields, such as wood engineering and construction, painting and finishing, glues and gluing, and preservative treatment, are included among these reports. A semiannual list of new publications is also issued.

Beginning January 1, 1963, the Laboratory instituted two completely new series of research papers and notes that will replace the present reports and technical notes. These will be issued as Forest Service Research Papers or Notes with the identifying letters FPL prefixed to each number. Scheduled as the first paper in the new series was No. FPL-1, "Characteristics of Alaska Woods." An entirely new format, greatly improved in readability and convenience, was adopted for both new series.



The "new look" in FPL research papers and notes. New series scheduled to begin January 1, 1963, replaces former series of reports and technical notes.

M 123 588

The 53 papers and articles published in trade and technical journals during 1962 reached many thousands of readers with business and professional interests in the forest products and related industrial and scientific fields. Some of these papers were presented at scientific and technical society meetings by their FPL authors.

Since users as well as producers and distributors of forest products have need of technical information available at FPL, information on new developments is also furnished to the mass communications media, the newspapers, magazines, radio, and television. In 1962, a total of 71 news releases were issued, ranging from brief announcements to comprehensive feature articles illustrated with "how-to-do-it" photographs. These articles were published in all parts of the United States.

Visitors

From 49 States and 55 foreign countries they came in 1962—people with the casual interest of the tourist and people with urgent research and production problems—to swell the visitor registration lists of FPL with 10,868 names. Of the total, 3,317 brought special problems concerning wood and its products.

Among foreign visitors were many from the Nations of Africa—The Republic of the Congo, Ivory Coast, Kenya, Liberia, Malagasy, Nigeria, South Africa, and Tanganyika. In national totals, Japan led with 47.

Some came in groups. Among these were, in April, 11 West German container manufacturers; in May, 3 Republic of China plywood manufacturers and 8 French and Swiss architects and engineers; in June, a 9-man Japanese pulp and paper research team; in August, 19 Latin American, Indian, African, and Near East attendees of an International Seminar on Soil and Water Conservation at the University of Wisconsin; in September, 12 Republic of the Congo students of government administration management, sponsored by the Agency for International Development; in October, 11 French particle board manufacturers; in November, 6 Brazilian vocational educators sponsored by AID; and in December, a 5-man Israeli group on plywood research and gluing.

FPL was host to many meetings and conferences of United States industry groups. A highlight of these gatherings was a Symposium on Fastenings for Wood in House Construction, cosponsored with the National Lumber Manufacturers Association. About 150 scientists, engineers, and industry officials attended the 3-day January meeting to discuss new methods of joining structural wood parts.

Other January meetings were held at FPL by NLMA's Technical Advisory Committee and its Special Committee on Technical Studies; the Committee on Wood of the American Society of Civil Engineers; the Research Advisory Committee of the American Wood Preservers Institute; and Committee D-7 on Wood of the American Society for Testing and Materials. The Technical Committee of the American Hardboard Association met here in February and again in November. The Exterior Packaging subcommittee of ASTM's Committee D-10 also met here in February, while its subcommittees on Tapes and Cushioning met in May.

The Advisory Committee on Waste Disposal of the Wisconsin Pulp and Paper Industry met at FPL in April. In May, the American Institute of Timber Construction held its annual meeting here and three pulp and paper organizations convened, the Lake States Section of the Technical Association of the Pulp and Paper Industry, the Lake States Technical Committee of the American Pulpwood Association, and the Research and Fellowship Committee of the Pulp Chemists Association. June brought the Midwest Society of Electron Microscopists and a pallet promotion clinic of the National Wooden Pallet Manufacturers Association.

French particle board manufacturers inspect sandwich panel with paper core in FPL loading machine.

M 122 368

M 121 868

U. S. Senator Gaylord Nelson, former Governor of Wisconsin, right, watches intently as Director Edward G. Locke explains operation of FPL's experimental paper machine.

The ASTM Task Group on Basic Stresses for Wood met in September and again in October. September also brought the Technical Committee of the Fibre Box Association; two industry advisory committees on fiberboard container research, one representing manufacturers and the other box users; and members of the Association of State Foresters holding their annual national meeting in Madison.

The Aerospace Industries Association and the Midwest Seasoning Association met at FPL in October, when the West Virginia Governor's Committee on Wood Utilization also came, and a military technical group coordinating packaging test standards in Federal Standard 101 conferred with FPL packaging specialists on revision work being done here. During November the Standing Committee on Commercial Standards for Southern Pine Plywood and the Research Advisory Committee for Pulp and Paper met here.

Scientific and Technical Meetings

The exchange of information with other scientists continues to be an important phase of FPL communications programs. During 1962, some 70 papers were presented by staff members at international, national, and regional meetings of this character.

Director Edward G. Locke appeared before eight such organizations. He delivered the keynote address at the fifteenth annual meeting of the Forest Products Research Society in Spokane, Wash., and in Dublin, Ireland, spoke to the Permanent Committee of the International Union of Forest Research Organizations, which he serves as chairman of its Forest Products Section. Other organizations to which Dr. Locke spoke were the Northeastern Lumber Manufacturers Association, the Southern Pine Association, the Association of State Foresters, the Kentucky Conservation Congress, the Ohio Valley section of FPRS, and the Texas Forestry Association.

Necmi Sanyer, a specialist in pulping processes, delivered a paper on eucalyptus pulping at a conference in Beirut, Lebanon, sponsored by the United Nations Economic, Social, and Cultural Organization.

Among national organizations at which scientific papers were delivered was the Technical Association of the Pulp and Paper Industry, the Society of American Foresters, the Forest Products Research Society, the Cellulose Research Institute, the Federal Fire Council, the American Society of Agricultural Engineers, the National Aeronautics and Space Agency, the American Society for Testing and Materials, the American Management Association, and the National Association of County Officials.

Regional organizations to which FPL staff members spoke included the Symposium on Wood and Fiber Quality in Relation to the Southern Pulp and Paper Industry at Raleigh, N. C.; the Eastern Pallet Users Conference; the Midwest, Mid-South, Southeast, Upper Mississippi Valley, and Inland Empire Sections of FPRS; the Mississippi Forestry Association and Mississippi Industrial and Technological Research Commission; A Forestry Symposium at Louisiana State University; the Douglas Fir Plywood Association; the West Coast Section, American Society for Testing and Materials; the New England Kiln Drying Association; the Western Section of the American Association of State Highway Officials; and the Lake States Section of TAPPI.

Foreign Assistance

Occasionally, FPL staff members are called upon to give expert assistance and advice to United Nations organizations. One such request took G. H. Chidester, chief of FPL's Division of Wood Fiber Products Research, to Thailand during August 1962. His assignment was to evaluate a proposal for economic and technical aid to the forestry and forest

industries of that Nation by the United Nations Special Fund. With him was Carl Ostrom, Washington, D.C., director of forest management research of the Forest Service.

Venezuela, Chile, and Brazil were visited in May and June by Dr. B. F. Kukachka, FPL's specialist in foreign woods and wood identification, and Dr. J. F. Saeman, chief of the Division of Wood Chemistry. Their trip was made to assist the Agency for International Development in building a program to foster research and development needed by wood-base industries of Latin America. They visited industrial concerns, plantations, forestry schools, and research institutions.

Demonstrations and Training

The "how-to-do-it" approach to putting research results to work reaches perhaps its greatest refinement in demonstrations, clinics, and the like. During 1962, FPL staff members conducted several such sessions for representatives of government and industry.

The demonstration attracting the largest enrollment was one in forest products utilization and marketing conducted for 56 foresters from 31 States. Subject matter included logging, sawmilling, grading, and other utilization aspects of forestry. Enrolled were timber management specialists of the USDA Forest Service and various State forestry officials, including Extension Service personnel working with private timber owners under the Federal–State Cooperative Forest Management Program.

An FPL technologist and log-grading expert went to Alaska to conduct a 2-week session for Alaskan forest workers on the grading of hardwood logs. Assisting him was a hardwood specialist from the Central States Forest Experiment Station. The session was an outgrowth of a visit to Alaska the previous January by another FPL sawmill specialist, who had recommended that a utilization program be preceded by careful evaluation of quality.

In late March and early April, FPL seasoning specialists conducted the 86th Kiln Drying Demonstration for 35 men, mainly operators and other employees of lumber, furniture, millwork, and associated companies. Those enrolled came from Canada, the Philippines, and Nepal as well as from 13 States, Alabama, Arkansas, Indiana, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, North Carolina, New York, Ohio, Washington, and Wisconsin. The series dates back to 1919. A surprising number from year to year are repeaters anxious to brush up on new, faster, more efficient drying techniques. FPL specialists conducted four clinics during 1962 for operators of sawmills. One was held in Denver, Colo., another at Casper, Wyo., and two at Neopit, Wis. The latter two were for members of the Menomonie Indian tribe, who operate a sawmill to cut timber from tribal lands formerly part of their reservation. The one-time reservation is now a Wisconsin county.

In July, FPL was host for a day to a group of 40 outstanding midwestern high school students attending a summer science training seminar at the University of Wisconsin under National Science Foundation sponsorship. A group of apprentice painters and decorators from West Allis, Wis., also spent a day here learning about wood.

But training was not limited to others. Staff members who use cameras in field work for record and other purposes were given photographic training. Twenty-five technical employees, mainly new personnel, were given a concentrated course in technical report writing.

Student Programs

The specialization demanded for forest products research is recognized in three FPL student training programs. One is conducted at the Laboratory for selected undergraduate college students. A second is carried on for graduate students at the University of Wisconsin, as part of a cooperative program in effect since FPL was founded in 1910. The third involves graduate research under grants of funds at various other universities.

The undergraduate student program consists of summer training jobs as laboratory assistants. During the summer of 1962, a total of 21 students from 12 colleges and universities in all parts of the United States took part; they were selected from more than 100 applicants. They participated in research projects in wood engineering, wood chemistry, pulp and paper, quality-growth relationships, seasoning, fire retardants, veneer production, statistical analysis, and scientific photography.

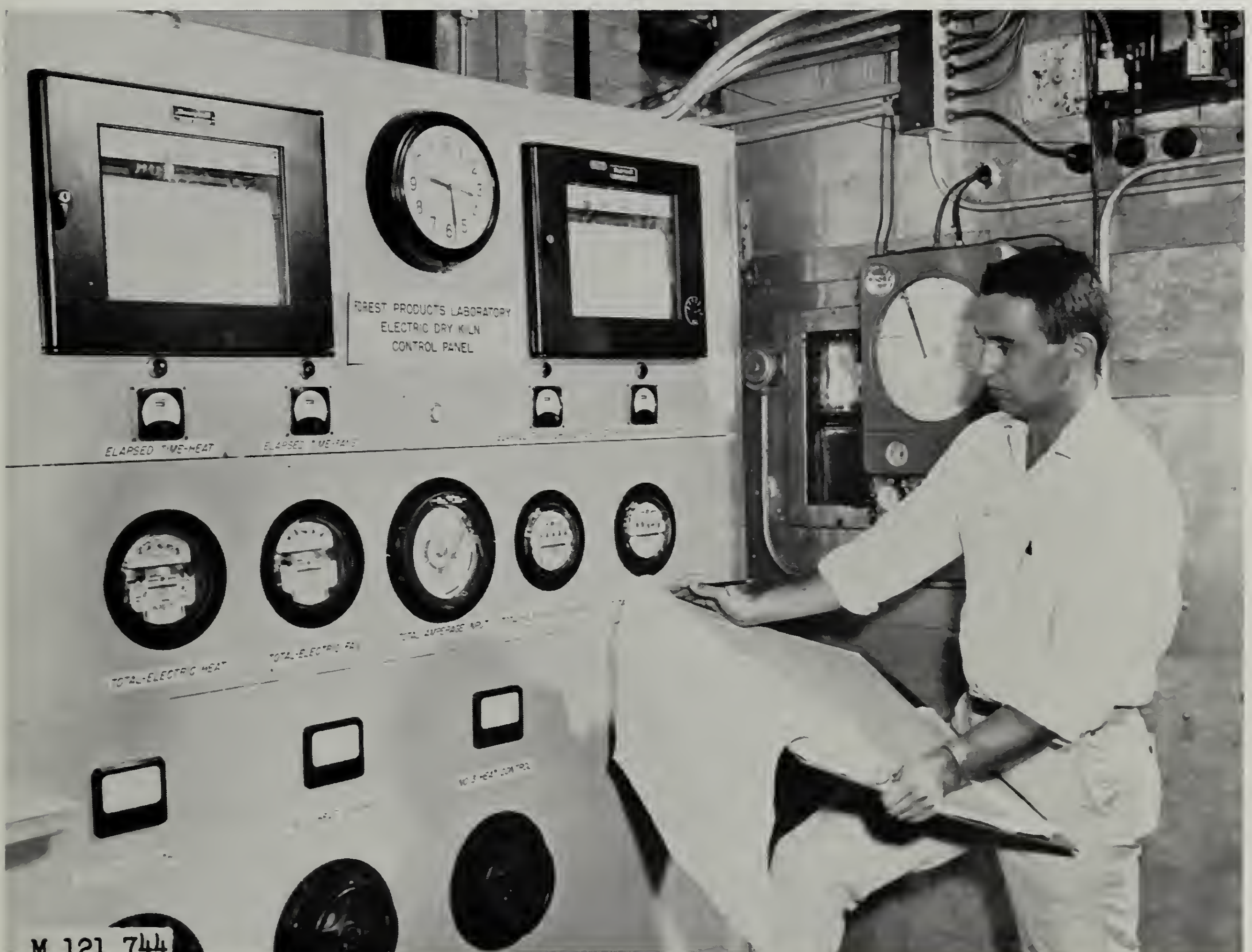
During the year, five University of Wisconsin graduate students conducted research at FPL to meet requirements for one master's and four Ph.D. degrees. They worked in the fields of forest products technology, bacteriology, pathology, structural engineering, and physics.

Under the third program, eight graduate students are working on advanced degree research, financed in whole or in part with FPL grants of funds. At the University of California, ponderosa pine stumpwood is being evaluated as a source of wood resin. At Oregon State University, the effects of jet streams of air-vapor mixtures on air movement, heat mass transfer, and other factors related to wood drying are under investigation.

A student at Colorado State University is study-

ing relationships between specific gravity and growth conditions for lodgepole pine. Growth-quality relations for western redcedar are being determined by a graduate student at the University of Idaho. As mentioned elsewhere in this report, a graduate student at the University of Michigan is studying wood cutting and machining with lasers and water jets. The important factors underlying initial infection of wood by decay fungi are being examined by a University of Minnesota graduate student.

At the New York State College of Forestry, a graduate student is working on the catalytic hydrogenation of lignin during pulping of wood. Some effects of microclimate on weathering of wood, wood products, and coatings and other treatments are being investigated by a University of Wisconsin graduate student.



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A summer job meant research on experimental drying of wood in an electric kiln at FPL for college student Thomas R. Waggener in 1962. Winner of a merit award of the Society of Wood Science and Technology, the Purdue graduate entered University of Washington for graduate study later in year.

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